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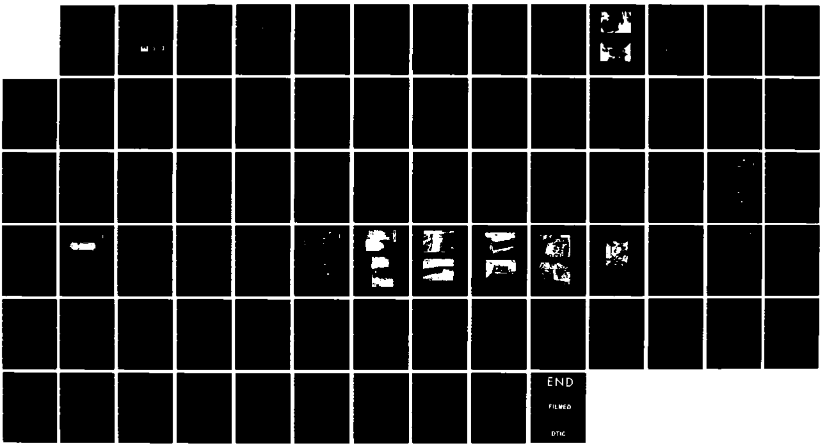

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MERRIMACK RIVER BASIN
STODDARD, NEW HAMPSHIRE

HIGHLAND LAKE SOUTH OUTLET

NH 00054

NHWRB 223.01

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

 AUGUST 1978

UNCLASSIFIED

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Merrimack River Basin
Stoddard New Hampshire
Contoocook River

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The dam is about 9 ft. high, and is a concrete and stone gravity dam which is founded on rock. The dam is classified as intermediate in size with a significant hazard potential. The condition of the dam is fair, although some preventive maintenance items require attention. The dam has successfully withstood major floods in the past without evident distress.

DISCLAIMER NOTICE

NATIONAL DAM INSPECTION PROGRAM

PHASE I INSPECTION REPORT

Inventory No.:	NH00054
NHWRB:	223.01
Name of Dam:	HIGHLAND LAKE SOUTH OUTLET
Town:	Stoddard
County and State:	Cheshire County, New Hampshire
Stream:	Moose Brook, Tributary to Contoocook River
Date of Inspection:	14 June 1978

BRIEF ASSESSMENT

The dam for the Highland Lake South Outlet lies at the southeast tip of the lake, 150 yards above the settlement of Mill Village in the town of Stoddard. The lake drains eventually to the Contoocook River in the Merrimack River Basin.

This dam is essentially a 9 foot high concrete and stone gravity dam which is founded on rock. Both abutments consist of concrete placed on massive, detached bedrock. The dam incorporates two control structures, a 51 foot long broad crested spillway and a 4 foot wide sluiceway equipped with stop-logs extending to the bottom of the dam. Appurtenant works include a 57 foot long riprapped South Dike, some 150 feet west of the right abutment, and 4.4 miles to the north on the eastern shore, the North Outlet. The North Outlet (NH00238) is the subject of an independent report, but it interacts hydraulically with the South Outlet and must be considered conjointly.

The dam was built in 1911 to consolidate a series of smaller ponds and was rebuilt in 1936. The drainage area is 29.7 square miles, and the normal storage is 7800 acre-feet. The dam's size classification is INTERMEDIATE and its hazard potential is SIGNIFICANT.

The dam's condition is FAIR, although some preventive maintenance items require attention. The dam has successfully withstood major floods in the past without evident distress. Although the Spillway Test Flood (STF) would greatly exceed the discharge capacity of the dam, there are no indications of potential instability even under that high flow.

The companion structure, the South Dike, displays seepage at its downstream toe under normal conditions.

The hydrological studies demonstrated the interdependence of the North Outlet and showed that discharge provisions on the lake need very substantial augmentation to accomodate the STF without overtopping.

Consequently, it is recommended that engineering studies be initiated to refine the hydrologic analyses with a view toward identifying a modification plan that would greatly augment discharge capacity, combining the studies with parallel investigations at the North Outlet. The studies should include methods of improving the South Outlet's downstream channel, particularly the bridge constriction, and optimum designs of zoned filters for the South Dike.

Operationally, the South Dike seepage should be monitored at least once per month for changes in turbidity and volume and a maintenance program should be established to include: sealing of open joints at cracks; repairing spalled and eroded concrete; and placing gunite, or otherwise suitably packing all voids, in the downstream dry rubble masonry. A warning plan should be developed and local public safety officials should be appropriately instructed and equipped to respond to flood emergencies at the dam.

The recommendations should be initiated in the near term, within 1 to 2 years after owner's receipt of the Phase I Inspection Report.

William S. Zoino, PE
N.H. Registration 3226

James H. Reynolds, PE
Mass. Registration 8044

PREFACE

This report is prepared under guidance contained in the "Recommended Guidelines for Safety Inspection of Dams " for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions will be detected.

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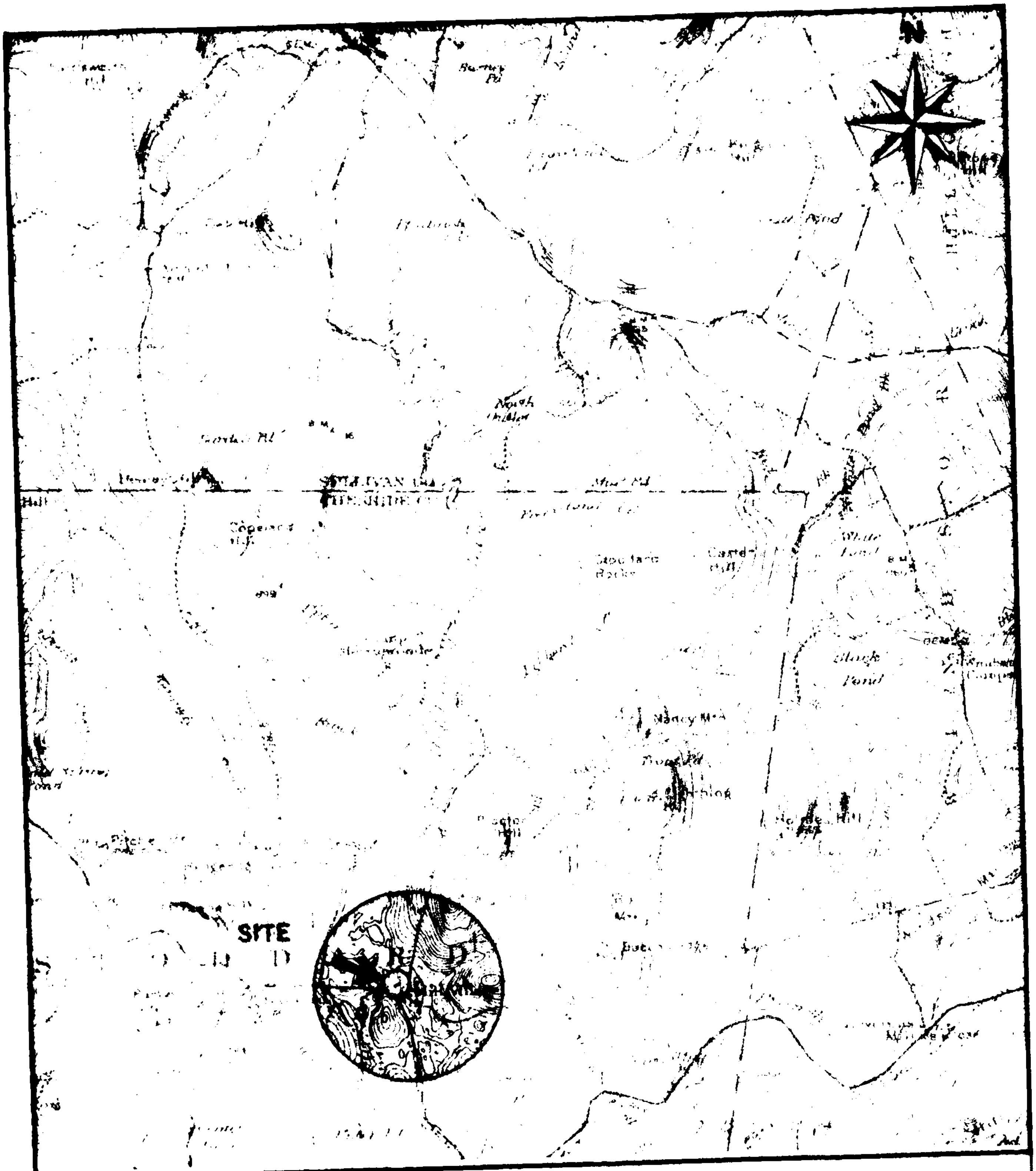
Overview photos of Highland Lake South Outlet



- SCALE -

0 1/2 1 1-1/2 2 miles

FROM USGS LOVEWELL MOUNTAIN, N.H. QUADRANGLE MAP

GEOTECHNICAL CONSULTANTS

NATIONAL DAM INSPECTION PROGRAM
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION

HIGHLAND LAKE SOUTH OUTLET NH00054
NHWRB 223.01

LOCUS PLAN

JULY 1978

PHASE I INSPECTION REPORT

HIGHLAND LAKE SOUTH OUTLET, NH00054

NHWRB 223.01

SECTION 1 - PROJECT INFORMATION

1.1 General

(a) Authority

Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Goldberg, Zoino, Dunnicliff & Associates, Inc., (GZD) has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed were issued to GZD under a letter of May 3, 1978 from Ralph T. Garver, Colonel, Corps of Engineers. Contract No. DACW33-78-C-0303 has been assigned by the Corps of Engineers for this work.

(b) Purpose

(1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

(2) Encourage and prepare the states to initiate quickly effective dam safety programs for non-Federal dams.

(3) Update, verify, and complete the National Inventory of Dams.

(c) Scope

The program provides for the inspection of non-Federal dams in the high hazard potential category based upon location of the dams and those dams in the significant hazard potential category believed to represent an immediate danger based on conditions of the dams.

1.2 Description of Project

(a) Location

The Highland Lake South Outlet lies at the southern end of Highland Lake, approximately 150 yards north of the post office/general store in the settlement of Mill Village near Stoddard, New Hampshire. The South Outlet flows into a tributary of the Contoocook River, which joins the Merrimack. The portion of the USGS Lovewell Mountain, New Hampshire quadrangle presented previously shows this locus. Figure 1 of Appendix B presents a detail of the site taken from the town tax maps.

(b) Description of Dam and Appurtenances

This dam is essentially a 9 foot high concrete and stone gravity dam which is founded on rock (Figure 2). Both abutments consist of concrete placed on massive, detached bedrock. The dam incorporates 2 control structures, a 51 foot long broad crested spillway and a 4 foot wide sluiceway equipped with stop-logs extending to the bottom of the dam.

Inspection of the impounded shoreline revealed the existence of a 57 foot long, 5.5 foot high earth and rock dike approximately 150 feet west of the right abutment (Figure 4, Photo 1). Investigations indicated that local residents built this dike in the late 1930's to prevent inundation of land developed after the construction of the dam, but which flooded at lake levels well within the design capacity of the South Outlet. This structure is discussed in greater detail in Section 3.

Although located some 4.4 miles from the South Outlet, Shedd Brook plays an important role in the lake as evidenced by its USGS designation as the North Outlet. While the original dam is no longer distinguishable from the natural shoreline, the brook still provides a channel which, if upgraded, could pass significant quantities of water. A separate report being prepared under the dam safety inspection program and Section 5 of this report discusses Shedd Brook, its related structures and its interaction with the South Outlet.

(c) Size Classification

The dam's normal impoundment of 7800 acre-feet places it in the INTERMEDIATE size category as defined by the "Recommended Guidelines".

The discharge-stage curve in Appendix D illustrates the outflow from each location plus the total outflow from the lake for any given stage. It is obvious that the STF of 15,000 cfs will result in significant overtopping at all three locations.

5.2 Hydraulic/Hydrologic Evaluation

The results of hydraulic and hydrologic assessments of Highland Lake Dam indicate that the maximum possible flow without overtopping of the road embankment across Shedd Brook and the South Dike is 2,000 cfs, which is considerably below the 15,000 cfs STF. Given the location of the South Dike, the discharge through that breach when combined with the overflow from the dam could cause significant damage to properties in the immediate vicinity of Mill Village. For the Spillway Test Flood to pass out of the lake, it is necessary to develop a lake water level of 8.6 feet above the spillway crest. At that stage, the flow in the vicinity of the dam is roughly 5,850 cfs; approximately 3,950 cfs would occur at the North Outlet and the remaining 2,000 cfs would go through the South Dike. The existing dam is, therefore, severely undersized to handle a STF criteria and guidelines.

5.3 Downstream Dam Failure Hazard Estimates

Use of the procedure set forth in "Rule of Thumb Guidelines for Estimating Downstream Dam Failure Hydrographs", Corps of Engineers, N.E.D., April 1978 permits estimation of the flood hazards in downstream areas that would result from a failure of the dam. This procedure incorporates the attenuation of the dam failure hydrographs in computing flows and flooding depths for downstream areas. These calculations take into account the hydraulic and storage characteristics of the stream reaches downstream of the dam.

While this dam can probably survive even the most severe overtopping, for the purposes of these calculations we have assumed that failure of the dam would occur when the depth of overtopping of the right abutment is 2.0 feet or when the east abutment is first overtopped, or at 1.33 feet above the spillway crest.

The evaluation divides the downstream channel into four reaches. The first reach is from the dam to the bridge at Mill Village. The second reach runs from the bridge to the end of the channel running through town. Reach three is the area of meanders as the stream approaches Island Pond and reach four is the Island Pond area. The

As the lake elevation continues to rise, two other outlets come into play. The first is Shedd Brook, or the North Outlet which is the subject of a separate Phase I Dam Safety Inspection report, but which requires consideration in conjunction with this dam. A road embankment with an 18 inch CMP culvert crosses the brook 500 feet downstream of the lake. The crest of the road is nearly level for approximately 100 feet at an elevation 3.5 feet above the spillway crest at the South Outlet.

The second overflow is a dike located approximately 150 feet west of the dam; the remainder of this report will refer to it as the "South Dike". The dike is 57 feet long with a crest elevation 3.7 feet above the spillway crest.

Analysis of the performance of the South Outlet during the STF involves the following assumptions concerning these 3 structures:

(1) Beaver dams at the 18 inch cmp obstruct all flow in Shedd Brook, as they have for at least the past 11 years.

(2) Breaching of the earth embankment on Shedd Brook occurs with overtopping on the order of 6 inches and a gap 40 feet wide by 4 feet deep results. This height of overtopping is equivalent to flow 4 feet over the spillway at the main dam.

(3) While heavy riprap protects the entire South Dike, sufficient flow may pass over the dike to cause its breaching. The analysis in Appendix D considers a breach 20 feet wide and 3.7 feet deep, or with bottom elevation equal to the spillway of the main dam. While breaching of the dike is hydraulically useful in that it permits assignment of additional flow to that area, survival of the embankment and its functioning as a submerged weir would not result in greatly increased flow at the other outlets or a significantly higher maximum lake level.

(4) All stop-logs are in place in the main dam at the time of the STF. This assumption, which is a distinct possibility based upon the discussion in Section 4, is a conservative one.

ability to safely allow an appropriately large flood to pass. This involves investigations to determine how the recommended Spillway Test Flood (STF) compares with the dam discharge and storage capacities. None of the original hydraulic and hydrologic design records were available for use in this study.

The "Recommended Guidelines" specify Spillway Test Flood criteria based on the size and hazard potential classifications of the dam. As shown in Table 3, for a dam classified as INTERMEDIATE in size with a SIGNIFICANT hazard potential, an appropriate STF is between 0.5 to 1 times the Probable Maximum Flood (PMF).

Use of the chart of "Maximum Probable Flood Peak Flow Rates" obtained from the NED provides a basis for estimating the PMF. The analysis uses a 30 square mile drainage area and a "rolling" terrain classification for Highland Lake. Use of the chart results in a maximum probable flow rate into the lake of 39,400 cfs, one half of which is 19,700 cfs.

The "Recommended Guidelines" suggest that where a range of STF is likely, the analysis should consider the magnitude that most closely relates to the involved risk. On this basis, since the risk is most likely at the lower end of the significant category, an STF of approximately one half the PMF is reasonable. The calculations contained in Appendix D, therefore used an uncorrected STF of 20,000 cfs. Applying the procedure suggested by the NED in "Estimating the Effect of Surcharge Storage on Maximum Probable Discharges, results in a final STF of approximately 11,800 cfs.

Attenuation of the STF is according to the storage-stage curve shown in Appendix D. This curve used a lake area of 712 acres and assumes a simple, linear storage vs. elevation above spillway crest relationship.

The discharge capacity of the South Outlet is dependent on the outlet characteristics and on the level of the water surface in the lake. Under most flow conditions, the spillway and weir outlet control the discharge from the lake. If the lake level overtops the spillway abutments, then the discharge capacity becomes dependent on the overall dam crest characteristics.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

(a) Design Data

The primary data sources available for The Highland Lake Dam are an "Inventory of Dams and Water Power Developments" by the New Hampshire Water Resources Board dated October 27, 1936 and "Data on Dams and Reservoirs in New Hampshire" by the New Hampshire Water Control Commission on August 30, 1939. These sources deal for the most part with the physical characteristics of the dam and its outlet works.

Other sources of data include several letters dated as recently as August 29, 1977 which relate primarily to the outlet works operations policy. This data indicates that the NHWRB operates the dam for spring flood control and summer recreational interests. During the fall the Board lowers the lake several feet by the removal of stop-logs from the sluiceway. During the spring high runoff period, the lake refills to its normal level.

(b) Experience Data

Records maintained by NHWRB since 1969 indicate that the dam crest has been overtopped in April 1969 and June 1973. In April 1969, water rose 1.5 feet above spillway crest with no stop-logs pulled. This created water levels 0.2 feet over the left side of the dam crest. In June 1973, water flowed 1.4 feet over the spillway crest with three stop-logs pulled. This created water levels 0.1 feet over the left side of the dam. No other information on experienced peak floods is known to be available for this dam.

(c) Visual Observations

The total area draining into the lake is 29.7 square miles and under normal conditions the lake has an area of 711 acres. The spillway is a relatively flat concrete and stone structure with a top width of 12 feet and a length of 51 feet. A single bay, stop-log sluiceway having a length of 4 feet controls the lake level.

(d) Overtopping Potential

The hydrologic conditions of interest in this Phase I investigation are those that are required to assess the adequacy of the dam in terms of its

4.5 Evaluation

For the paricular dam, the established operational procedures are adequate. Some improvement, however is possible, particularly in the area of decreasing response time in removing stop-logs.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures

As noted earlier the NHWRB has 2 roving dam operators who visit all dams under the Board's jurisdiction on a 7 to 10 day cycle. These individuals adjust the lake levels as the Board's engineering section. When the Board receives complaints from area residents about lake levels or flow conditions, the engineering section validates the complaint with a local agency such as the police or fire department and then sends an operator if necessary.

The Board's chief engineer maintains a list of these dams particularly susceptible to flash flooding. During severe storms, operators visit these dams first. Should conditions require more dam operations than the regular operators can handle, the Board's engineers have the equipment and training to operate the dams.

At the end of the summer, the Board sets the lake level at 3 to 4 feet below the spillway in anticipation of fall storms and spring runoff.

4.2 Maintenance of Dam

The dam operators report any maintenance problems to the engineering section. They, in turn, assess the problem an initiate whatever corrective measures are necessary.

4.3 Maintenance of Operating Facilities

The stop-log sluiceway requires only routine maintenance as discussed above.

4.4 Description of Any Warning System in Effect

The NHWRB relies on its dam operators to detect any probelms which would adversely affect dam safety. While not formally established, the continuous interest of local residents, ample evidence of which is found in the Board's correspondence and phone logs, provides a secondary, but effective, warning system.

the right abutment, the team noted clear seepage on the order of 1 gpm (Photo 9); water was also flowing from several smaller seepage points within a distance of 5 feet on either side of the large one.

(d) Reservoir

An inspection of the reservoir shore revealed no evidence of movement or other instability. While sedimentation was heavy immediately behind the spillway, the total quanity was negligible in terms of the reservoir capacity. An examination of the surrounding area revealed no work in progress or recently completed which might increase the flow of sediment into the lake. Additionally, the team noted no changes to the surrounding watershed which might adversely affect the runoff characteristics of the basin.

A considerable amount of the development in this area is seasonal in nature and is directly on the lake shore. Were the probable maximum flood to occur with the lake at normal level and were lake levels to rise on the order of 8 feet, significant property damage would result to homes and cottages all around the lake shore.

(e) Downstream Channel

The team observed no downstream conditions which adversely affect the operation of the dam or which pose a hazard to the safety of the dam. The downstream road bridge (Figure 1), however, could not pass the SDF without creating high tailwater levels at the dam.

3.2 Evaluation

Because the dam is of simple design and because its major structural components are accessible for examination, the visual inspection permitted satisfactory evaluation of those items which affect the stability and safety of this structure.

The east abutment, which is approximately 26 feet long and 5.5 feet wide, is also similar in construction to the spillway and the west abutment except that the top surface has only a partial concrete cap. Either rubble stone masonry or a bedrock outcrop are higher in elevation than the adjoining concrete surfaces. Vegetation covers approximately 10% of the abutment surface. The exposed downstream rubble wall face does not show any sign of displacement. The end of this abutment also ties into detached bedrock.

The rock which forms the foundation and downstream area of the dam and into which the abutments tie consists primarily of quartz monzite. The rock is tightly jointed and shows only slight weathering. The rock masses at the abutments, while quite massive, are detached from the parent bedrock. However, close inspection of the formations revealed no evidence of movement or seepage through these areas.

(4) Buttress (Photos 7 and 8)

The dam contains an intermediate buttress constructed between the spillway and the sluiceway and founded on rock. This buttress consists of dry rubble stone masonry with concrete facing on the upstream side and its top surface. The downstream side of the buttress consists of rubble stone set on a near vertical plane. Portions of this masonry directly under the surface slab are missing, as is stone at the base of the rubble. The top concrete surface shows evidence of erosion and contains spalls and wide random cracks. Grass flourishes in the cracks.

(c) Appurtenant Structures

The appurtenant structure of greatest concern is the earth dike to the west of the right abutment. Originally constructed as a rock and earth filled timber crib in the late 1930's, residents apparently enlarged it and added heavy riprap on all surfaces in recent years. The crest of the dike is approximately 3.7 feet higher than the center of the spillway. At a point on the toe of the downstream slope, 34 feet from

SECTION 3 - VISUAL INSPECTION

3.1 Findings

(a) General

The Highland Lake South Outlet is in good condition at the present time. The dam requires no immediate remedial measures for continued safe operation under normal conditions. It does, however, require some maintenance work, the details of which Section 7 presents.

(b) Dam

(1) Spillway (Photo 2)

The spillway is 51 feet long and has a crest width of 12 feet. The free fall over the spillway varies from approximately 3 feet to 9 feet. The surface of the spillway consists of a concrete cap, approximately 6 inches thick, placed on dry rubble stone masonry. The downstream slope of the exposed dry rubble stone masonry varies from the vertical to approximately 2 in 12. There is no evidence of spalls, cracks or other deficiencies on the spillway crest. The near vertical dry rubble stone masonry does not show any evidence of displacement.

(2) Sluiceway (Photos 3 and 4 , Figure 3)

The structure includes a concrete sluiceway equipped with stop-log slots approximately 11 feet east of the spillway. The sluiceway is 4 feet wide and approximately 9 feet high. A concrete safety walkway 5 feet wide and 6 inches in thickness spans over the sluiceway. At the time of inspection, the sluiceway contained approximately 7 vertical feet of stop-logs.

(3) Abutments (Photos 4, 5 and 6)

The west abutment, which is approximately 15 feet long and 12 feet wide, is similar in construction to the spillway. Medium random cracks and efflourescence are prevalent on the vertical surfaces of the concrete portion of the abutment. The exposed downstream rubble wall face does not show any sign of displacement. This abutment ties into detached bedrock.

SECTION 2 - ENGINEERING DATA

2.1 Design

The design of the present structure is quite simple and appears adequate in all respects except ability to pass the Spillway Test Flood (STF). Plans for neither the original nor the rebuilt structure are available.

2.2 Construction

Visual inspection of the dam detected only minor construction deficiencies in the structure. In some areas, apparent overworking or over vibration of the concrete has resulted in exposed aggregate. At one location on the downstream face, large voids exist in the mortar bound rubble probably due to inadequate setting of rubble in the concrete. Overall, the quality of construction is probably as good as can be expected for a structure of this type built during this period.

2.3 Operation

Prior to state ownership, area residents found it necessary on several occasions to call the Public Service Company in order to get stop-logs pulled during periods of high water. The State only performs this function routinely in the Fall of each year.

2.4 Evaluation

As mentioned above, the original plans for this dam are not available, if indeed they still exist. Previous inventory reports, sketches and correspondence concerning the dam, supplemented by the observations of the inspection team and interviews with local residents form the basis of the information presented herein. Thus, for the combined information from all sources affecting dam evaluation, the availability, adequacy, and validity of the relatively sparse data can only be considered marginal. However, since the observations by the inspection team generally confirm the available written data and statements of residents, the data are considered as satisfactory bases upon which to form an evaluation.

(2) Length: 108 feet

(3) Height: 8± 1 feet

(4) Top Width: 12 feet

(5) Side Slopes: Not Applicable

(6) Zoning: Not Applicable

(7) Impervious Core: Not Applicable

(8) Cutoff: Unknown

(9) Grout Curtain: Unknown

(h) Spillway

(1) Type: Concrete and stone, broad crested.

(2) Length of Weir: 51 feet 3 inches

(3) Crest Elevation: 1296± feet

(4) Gates: None

(5) Upstream Channel: Shallow approach, full width of dam

(6) Downstream Channel: Small pond with numerous rock outcrops

(i) Regulating Outlets

The dam includes a 4 foot wide sluiceway with stop-logs near the left abutment (Figure 2). Approximately 7 feet of stop-logs were in place at the time of the inspection. The stop-logs require manual removal and a bar lock secures them in the dam. The invert of the sluiceway is at Elevation 1289±.

(c) Elevation (feet above MSL)

(1) Top Dam: West Abutment 1298.6±
East Abutment 1297.3± (Estimated minimum)

(2) Maximum pool-design surcharge: 1297.3±

(3) Full flood control pool: Not Applicable

(4) Recreation pool: 1296±

(5) Spillway crest: 1296±

(6) Upstream portal invert diversion tunnel: Not Applicable

(7) Streambed at centerline of dam: 1287±

(8) Maximum tailwater: Unknown

(d) Reservoir

(1) Length of maximum pool: Unknown

(2) Length of recreation pool: 5.5 miles

(3) Length of flood control pool: Not Applicable

(e) Storage (acre-feet)

(1) Recreation pool: 7800±

(2) Flood control pool: Not Applicable

(3) Design surcharge: 7800±

(4) Top of dam: 7800±

(f) Reservoir Surface (acres)

(1) Top dam: 712±

(2) Maximum pool: 712±

(3) Flood control pool: Not Applicable

(4) Recreation pool: 711

(5) Spillway crest: 711

(g) Dam

(1) Type: Concrete and stone gravity

(i) Normal Operational Procedures

The NHWRB has two roving dam operators who visit all dams under the Board's jurisdiction on a 7 to 10 day cycle. Section 4 discusses the operational procedures employed in greater detail.

1.3 Pertinent Data

(a) Drainage Areas

Highland Lake receives runoff from a 29.7 square mile drainage area. Approximately 65% of this area is on the west side of the lake, as the terrain to the east slopes away from the lake at the northern end. Tributaries of the lake include Kennedy, Rice and Upton Brooks to the west, Halfmoon and Philbrick Ponds to the north and Freezeland Creek, Pictarel Creek and Carr Brook to the east. The terrain is heavily forested and steeply sloping, rising approximately 300 feet within one mile of the shoreline on both sides. There is limited year-round development around the lake. The majority of the structures are summer cottages.

(b) Discharge at Dam Site

The NHWRB has maintained records of water surface elevation at Highland Lake since 1968. During this ten year period the largest floods occurred in April of 1969 and June of 1973. In 1973, there was 1.4 feet over the spillway with 3 stop-logs pulled. In 1969, there was 1.5 feet over the spillway with the stop-logs in place. These flows are the maximum from recorded data at the dam, but in March of 1936 considerably greater flood depths probably occurred based on total runoff downstream at the USGS gauge near Antrim, N.H. The maximum discharge at that gague occurred on March 19, 1936 with an estimated discharge of 5000 cfs. This yields a runoff rate of 91.2 cfs. per square mile if uniformly distributed. The drainage area of the lake is 29.7 square miles which would result in an approximate peak discharge of 2700 cfs. The stage-discharge data contained in Appendix D indicates that 4.5 ft. of head above the spillway would be required to produce an outflow of that magnitude at the south end of the lake.

(d) Hazard Potential Classification

The location of several permanent dwellings and the local fire department immediately downstream of the dam and the potential damage to Rt. 123 warrant a SIGNIFICANT hazard potential classification.

(e) Ownership

The Public Service Company of New Hampshire owned the dam until 1968. At that time, after some maintenance work, the New Hampshire Water Resources Board (NHWRB) assumed possession.

(f) Operator

The NHWRB controls the operation of the South Outlet. Key officials are: Chairman George McGee, Chief Engineer Vernon Knowlton, Assistant Chief Engineer Donald Rapoza and Staff Engineer Gary Kerr. The Board's telephone number is (603) 271-3406. It may also be reached through the State Capital Operator at (603) 271-1110.

(g) Purpose of Dam

While formerly used for storage and as a control dam for power generated at a downstream site in Hillsborough, the dam now serves only recreational purposes with minor flood control functions.

(h) Design and Construction History

No significant information is available for this dam. A 1936 inspection report by the New Hampshire Water Resources Board indicates that rebuilding of the dam took place in that year, probably resulting in its present configuration. Initial construction was apparently somewhat earlier, as some records alluded to the dam in 1911. Placement of the dam did result in the consolidation of three smaller bodies of water, one of which was Long Pond, into what is now Highland Lake. Contact with the previous owner, Public Service Company of New Hampshire, the present owner, the NHWRB, and officials in the town of Stoddard provided no plans for the structure. The available reports make mention of one A.T. Hotchkiss as the architect/engineer for the reconstruction.

simplified analysis used predicts that the average flow depths in each of the reaches are not sufficient to cause severe flooding. This result is reasonable for reaches 2, 3, and 4. For reach one, the simplified procedure probably does not adequately consider the backwater from the restriction at the bridge. It is believed that significant flood potential will exist in the area between the dam and bridge and that this area requires more detailed analysis before establishing an estimated flood depth.

SECTION 6 - STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

(a) Visual Observations

The extensive field investigation of the dam indicated no significant displacements and/or distress which would warrant the preparation of structural stability calculations based on assumed sectional properties and engineering factors.

(b) · Design and Construction Data

As mentioned previously, a check of records held by the past and present owners and by town officials yielded no plans or calculations of value to a stability assessment.

(c) Operating Records

Neither the Public Service Company of New Hampshire nor the NHWRB have the pre-1969 operating records. The engineering section of the Board holds the operating records since 1969. These records reveal no evidence of instability during the floods recorded in April 1969 and June 1973.

(d) Post Construction Changes

The results of the field investigation and a check of available records produced no evidence of changes to the dam or surrounding area that would influence stability of the structure.

(e) Seismic Stability

Paragraph 3.6.4 of the "Recommended Guidelines" permits the assumption of no earthquake hazards for structures in Seismic Zone 2 which show no obvious static stability problems, as is the case with this dam.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

(a) Condition

The condition of the dam for Highland Lake's South Outlet is FAIR, and there are no indications of potential instability.

However, the Spillway Test Flood would greatly overtop the South Outlet, would seriously threaten the South Dike to the west of the right abutment and would create very large flows in Shedd Brook. The following discusses each occurrence individually.

Based on the visual inspection, the South Outlet could probably survive an overtopping by the STF, the dam functioning as a submerged weir. The large discharge over the dam would most likely wash out the roadway just south of the dam and those structures near the channel and around Island Pond would suffer considerable damage from flooding. The rising lake level created by the inability of the dam to pass the very high flow of the STF would also damage about 100 residences around the lake shore. Loss of life is unlikely, as evacuation measures would have already taken effect.

Overtopping the South Dike would release a significant amount of water into the low area to the west of Eaton's store (Figure 1). The water would most likely cause some damage to Rte. 123 before rejoining the downstream channel of the main dam somewhere between Mill Village and Island Pond. Again, loss of life from this individual event is unlikely. Similar flooding would occur in the Dead Brook area.

Increased flow in Shedd Brook likewise presents more danger of property damage than loss of life, since there is no significant downstream development for a distance of at least 6 miles.

(b) Adequacy of Information

An adequate assessment of this structure consistent with the scope of a Phase I investigation was possible based upon the visual inspection, the existing records and the information provided by local residents.

(c) Urgency

Recommendations below should be initiated in the near term, within 1 to 2 years of owner's receipt of the Phase I Inspection Report.

(d) Need for Additional Information

There is a need for a refined hydrologic analysis under separate study, to be combined with feasibility studies for the improvement of the North Outlet as an emergency spillway.

7.2 Recommendations

The primary deficiency of the South Outlet is not its structural integrity, but its inability to pass even moderate floods without overtopping. Additionally, this inability to pass the flood brings other features of the lake into play, primarily the heavily riprapped South Dike and the North Outlet, or Shedd Brook. To resolve these problems, the owner should initiate engineering studies and refined hydrologic analysis to assist in identifying a modification plan that would greatly augment lake discharge capacity. Such an investigation would necessarily involve the North Outlet, or Shedd Brook. A single report should be prepared for the lake as an entity. The studies should include:

(a) Upgrading of Shedd Brook and its intervening structures to permit passage of that portion of the STF which the South Outlet cannot safely handle. While the North Outlet Dam (NH00238) is the subject of a separate report in this series, its interaction with the South Outlet requires concurrent consideration.

(b) Investigating the optimum design for zoned filters at the downstream of the South Dike and initiating a program to monitor seepage through this structure, at least once per month. While the present height of the dike is sufficient for the storm of record, the STF would significantly overtop it. To raise the height of the dike to that consistent with the STF is not practical, as it would involve extending the dike upstream to prevent flanking, thereby isolating the nearby shore front homes from the lake.

7.3 Remedial Measures

(a) Alternatives

The only apparent alternative to greatly increasing discharge capacity appears to be breaching of the dam.

(b) O and M Procedures

As a matter of prudent maintenance programming and operational reliability, the following should be implemented:

(1) Seal all joints and cracks and maintain them free of debris and vegetation.

(2) Repair all areas of spalled and eroded concrete.

(3) Pack all voids in the downstream dry rubble stone masonry by guniting, or by other suitable techniques, to prevent the loss of additional material.

(4) Decrease the response time in opening the outlet works in an emergency. The NHWRB should consider delegating some operational responsibility to a local official such as the police or fire chief. This individual or his delegate would maintain a set of keys to the stop-logs for use in an emergency as directed by the NHWRB.

APPENDIX A

VISUAL INSPECTION CHECKLIST

INSPECTION TEAM ORGANIZATION

Date: 14 May 1978 - 9:30 A.M.

Project: NH00054
Highland Lake South Outlet
Mill Village, Stoddard, New Hampshire
Moose Brook
NHWRB 223.01

Weather: Sunny, Warm

Inspection Team

James H. Reynolds	Goldberg, Zoino, Dunnicliff & Associates, Inc. (GZDA)	Team Captain
William S. Zoino	GZDA	Soils
John E. Ayres	GZDA	Geology
Nicholas A. Campagna	GZDA	Soils
Robert Minutoli	GZDA	Soils
Paul Razgha	Andrew Christo Engineers, Inc.	Structural & Me
Richard L. Laramie	Resource Analysis, Inc.	Hydrology

State Official Present

No NHWRB representative available

TEAM MEMBERS CHECK LISTS FOR VISUAL INSPECTION		
AREA EVALUATED	BY	CONDITION & REMARKS
SUPERSTRUCTURE		
General		
Vertical alignment and movement Horizontal alignment and movement		No vertical or horizontal movement or alignment problems noted
Condition of abutments		No deficiencies in rock abutments noted
Abutment slope protection		No protection required
Unusual movement or cracking at or near toe		Rock at toe of dam not completely visible due to water over spillway, but appears to be in good condition
Unusual downstream seepage		No downstream seepage noted
Foundation drainage features		No foundation drainage visible
Condition of Concrete		
Erosion or cavitation		Erosion noted in buttress between spillway and left abutment
Spalling		Spalling in buttress between spillway and left abutment
Cracking		Random cracks at right abutment and in buttress between spillway and left abutment. Vegetation in buttress area cracks.
Condition of joints (sealing, alignment, etc.)		Left abutment concrete fair with some vegetation in joints.
Rusting or staining of concrete		None
Visible reinforcing		None
Seepage or efflorescence		Efflorescence at right abutment

TEAM MEMBERS CHECK LISTS FOR VISUAL INSPECTION		
AREA EVALUATED	BY	CONDITION & REMARKS
Condition of Rubble Bound in Concrete		Some rubble stone missing on downstream face between sluiceway and spillway. Right abutment fair Left abutment fair Fair condition below spillway (water flowing)
SOUTH DIKE		
Vertical & horizontal alignment	M.A.C. MLR	Good
Surface cracks		None
Slopes		Good condition, no sloughing or erosion
Riprap		Good
Seepage		One gpm clear seep 34 ft from right abutment at toe of downstream slope. Several smaller seeps within 5 ft of larger seep on either side.
OUTLET WORKS		
Approach Channel		
Slope conditions	MAC	No slopes on approach channel
Bottom conditions		Siltation behind spillway-water depth 6" on right side and 3'4" on left side
Rock slides or falls		No evidence of slides into chamel
Log boom		No log boom
Control of debris		No debris noted behind spillway
Trees overhanging channel		No trees
Concrete Spillway		
Concrete		Fair some exposure of aggregate
Erosion or cavitation		None

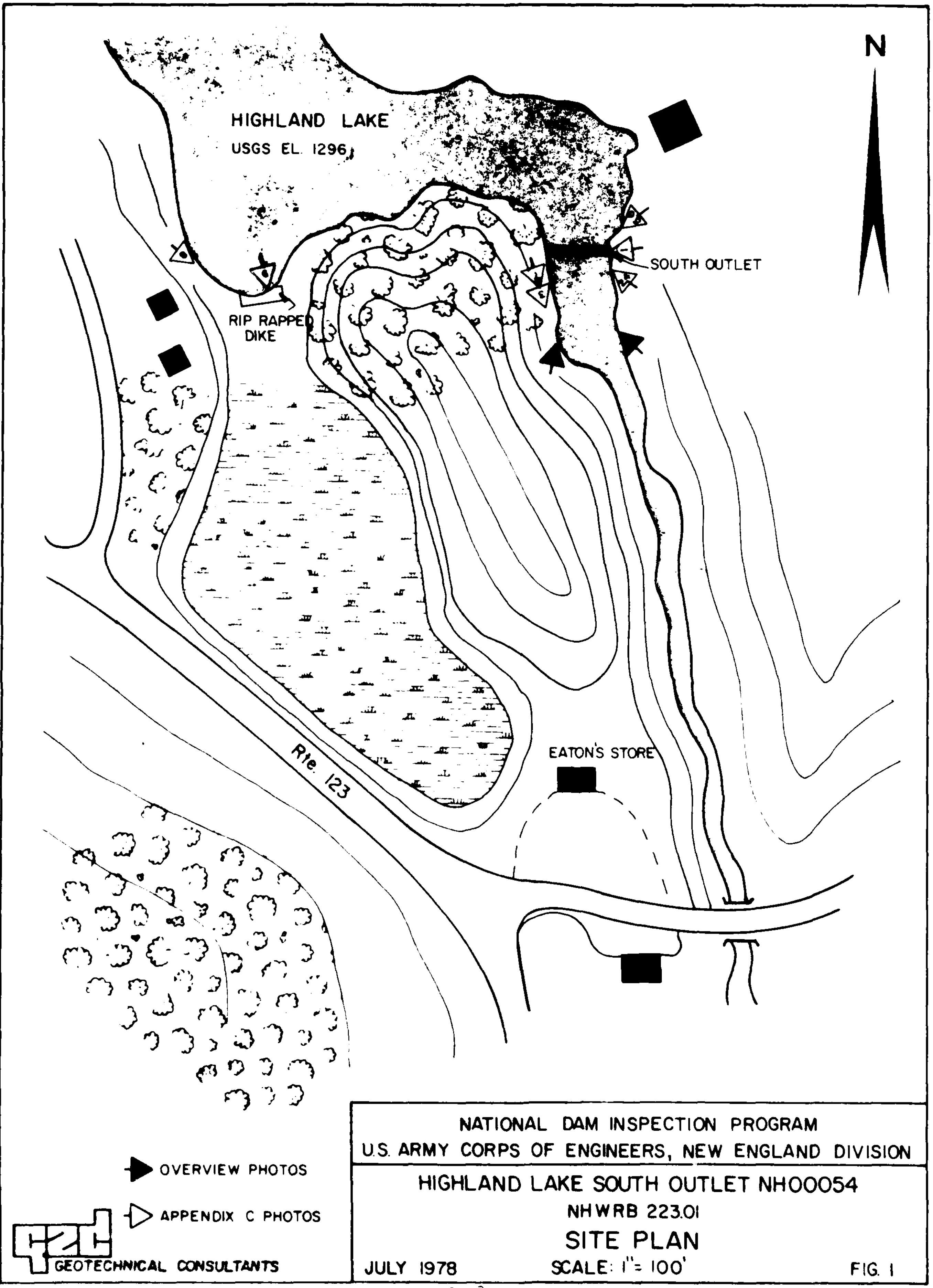
TEAM MEMBERS CHECK LISTS FOR VISUAL INSPECTION		
AREA EVALUATED	BY	CONDITION & REMARKS
Concrete Spillway (cont.)		
Spalling		None
Cracking		No cracks visible (water flowing)
Rusting or staining		None
Visible reinforcing		None
Any seepage or efflorescence		None
Stop-Log Sluiceway		
Condition of stop-logs		Good
Condition of concrete retaining slots (see items for concrete above)		Condition of concrete fair, no cracks or spalling noted
Adequately secured (tamper proof)		Locked in place with bar
Outlet Channel (immediate area)		
Slope conditions		Downstream slope of dam primarily rubble bound in concrete and bedrock outcrops
Rock slides or falls		None
Debris		None
Trees overhanging channel	MLC	One small tree over channel presents no problem
Erosion at toe of dam		No major erosion of bedrock - appears massive, tightly jointed and in good condition.
Existence of gages		NHWRB uses top of spillway as gage
RESERVOIR		
Shoreline		Shoreline stable to 500 feet upstream on either side.

Highland Lake South Outlet
Moose Brook, Mill Village (Stoddard)NH

June 14, 1978
NH00054

TEAM MEMBERS CHECK LISTS FOR VISUAL INSPECTION		
AREA EVALUATED	BY	CONDITION & REMARKS
RESERVOIR (cont.)		
Sedimentation	AHR	Sedimentation behind spillway (see spillway comments)
Upstream hazard areas in the event of backflooding		Several beach front homes subject to inundation if lake rises 3-5 feet.
Changes in nature of watershed (agriculture, logging, construction, etc.)		No changes noted - watershed primarily forest
DOWNSTREAM CHANNEL		
Restraints on dam operation	MRC	Large diameter culvert under road 400 feet downstream from dam. Channel has steep sides and flows into Island Pond ½ mile downstream.
Potential flooded areas		Several downstream buildings at approximately the level of top of dam.
OPERATION AND MAINTENANCE FEATURES		
Reservoir regulation plan		
Normal procedures		Lake lowered after Labor Day
Emergency procedures		Good response time but could be improved by assigning stop-log keys to local police or fire personnel.

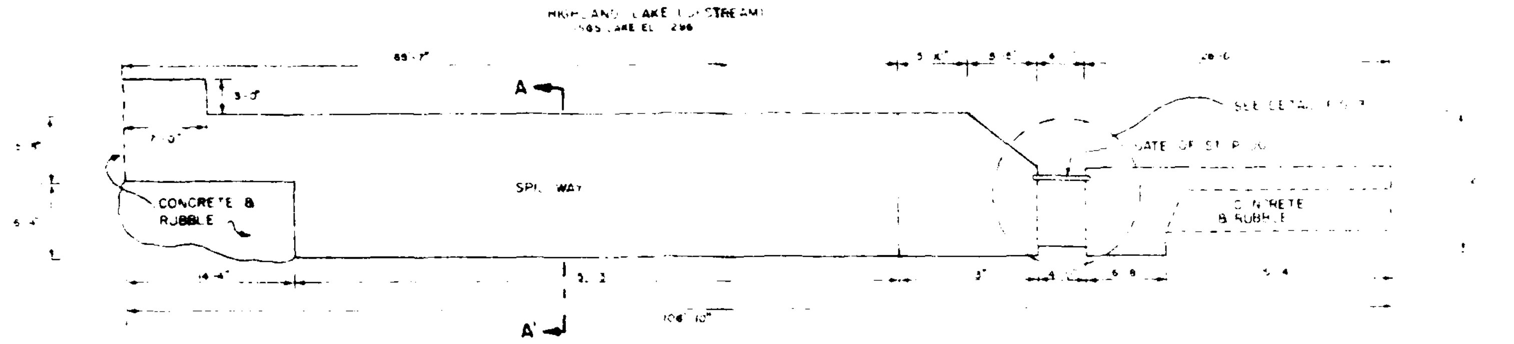
Appendix B



NATIONAL DAM INSPECTION PROGRAM
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION

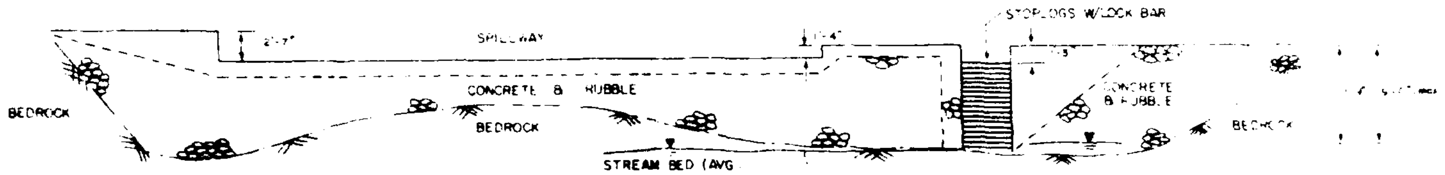
HIGHLAND LAKE SOUTH OUTLET NH00054
NHWRB 223.01
SITE PLAN

JULY 1978 SCALE: 1"= 100' FIG. 1



PLAN

SCALE 1"=10'



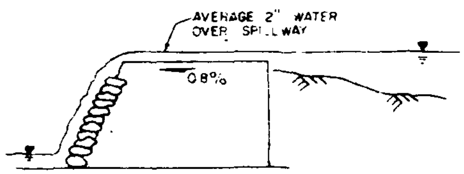
DOWNSTREAM ELEVATION

SCALE 1"=10'

NOTES

1) DEPTH OF WATER BEHIND SPILLWAY VARIES FROM 6" AT RIGHT SIDE TO 1'-4" AT LEFT SIDE DUE TO VARYING DEGREES OF SILTATION

2) ALL WATER LEVELS MEASURED 14 JUNE 1978



SECTION A-A'

SCALE 1"=10'

NATIONAL DAM INSPECTION PROGRAM
US ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION

HIGHLAND LAKE NH 00054
NH WRB 223.01

PLAN, ELEVATION AND SECTION

DAMS 148 HIGHLAND LAKE #1 6-28-78 DW 1 of 24

SIZE CLASSIFICATION: INTERMEDIATE

HAZARD CLASSIFICATION: SIGNIFICANT

DOWNSTREAM HOMES [illegible] [illegible] SOUTH DIKE [illegible] SIGNIFICANT [illegible]

SPILLWAY TEST FLOOD

$\frac{1}{2}$ PMF → PMF

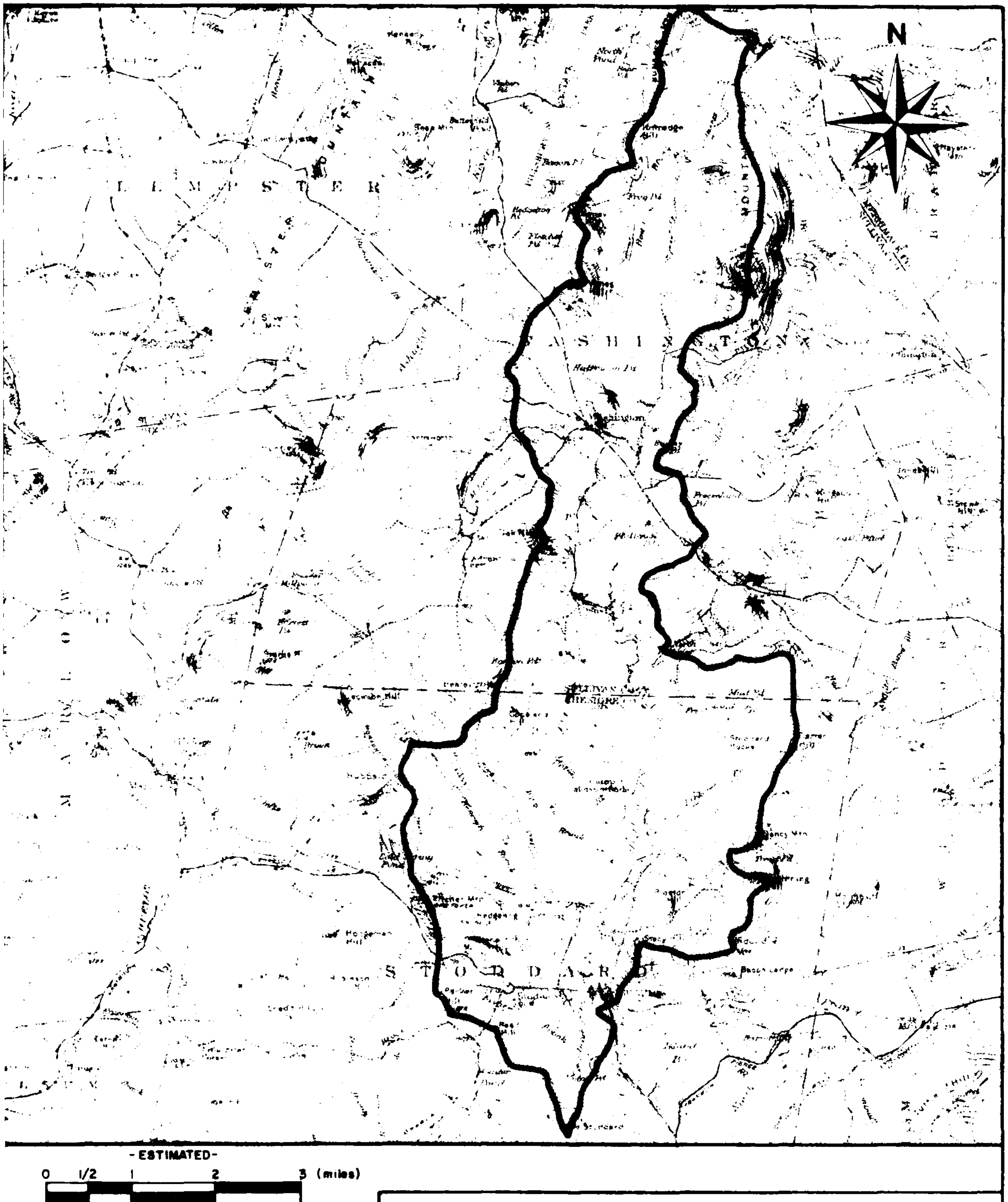
FROM THE CURVE [illegible] ROLLING [illegible] AND [illegible]

⇒ 1325 cfs/mi²

PMF = 29.7(1325) = 39353 cfs

GIVEN THE UNCERTAINTY OF [illegible] DAM SHOULD BE LOW OR SIGNIFICANT HAZARD, [illegible] USE THE ½ PMF VALUE

STF = 20,000 cfs



NATIONAL DAM INSPECTION PROGRAM
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION

HIGHLAND LAKE SOUTH OUTLET NH00054
NHWRB 223.01
DRAINAGE AREA

GEOTECHNICAL CONSULTANTS

JULY 1978

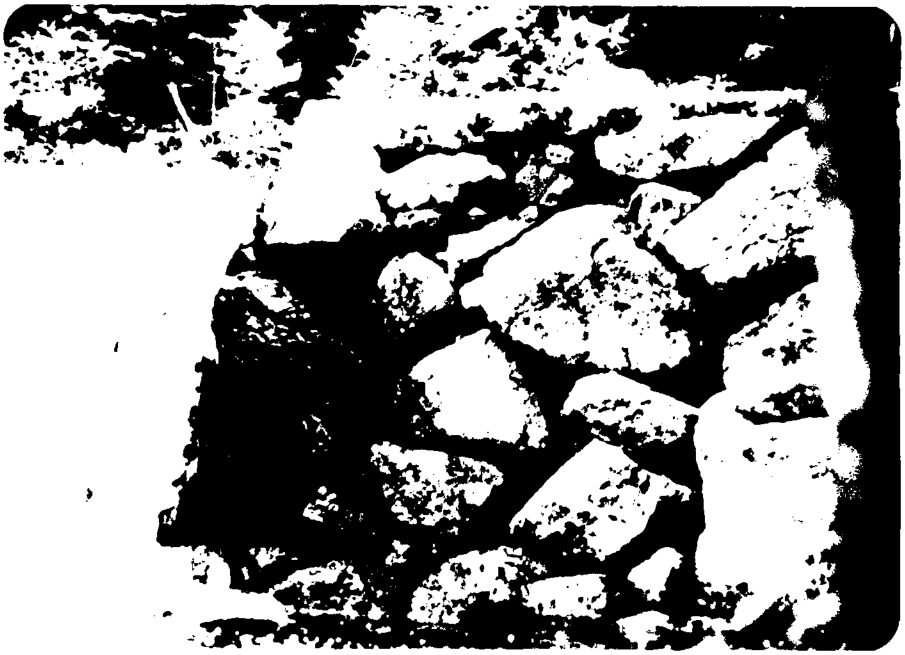
APPENDIX D

HYDROLOGIC & HYDRAULIC COMPUTATIONS

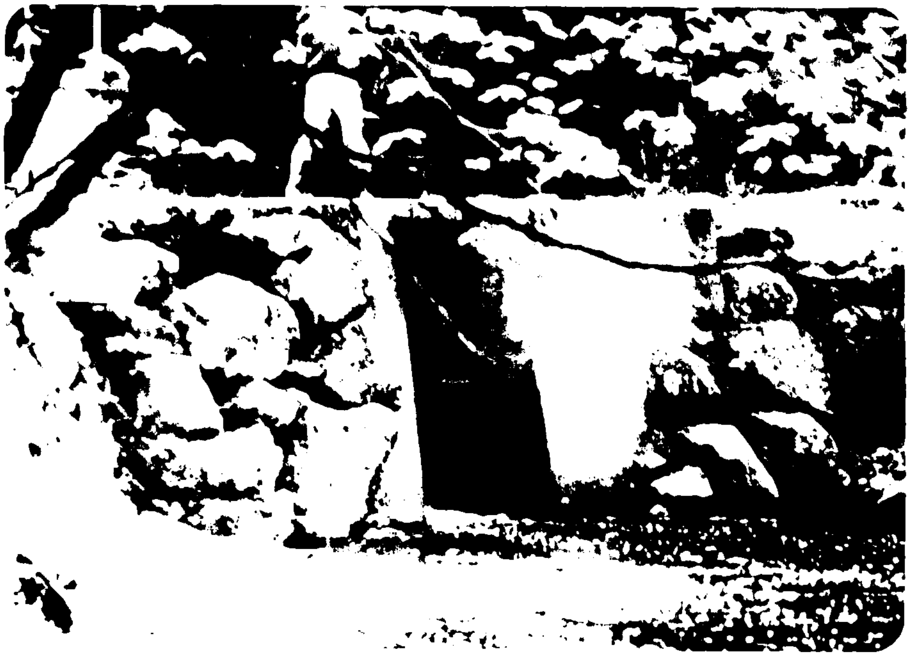
FOR

HIGHLAND LAKE SOUTH OUTLET

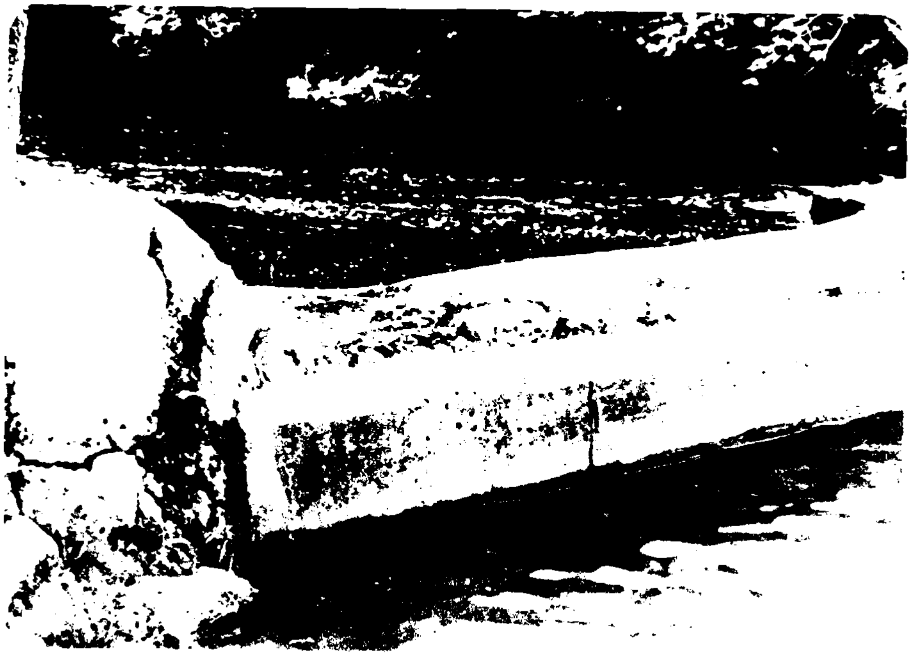
9. Seepage at downstream toe of rock filled earth dike as seen from crest of dike



7. View of buttress from right side downstream



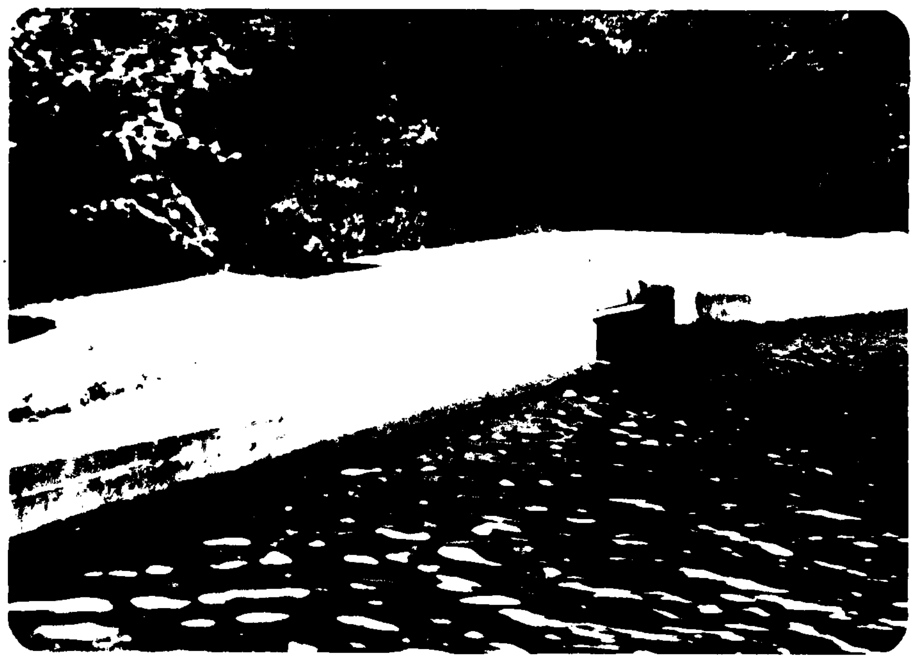
8. View of buttress from left side downstream



5. View from upstream of left abutment

6. View from downstream of right abutment

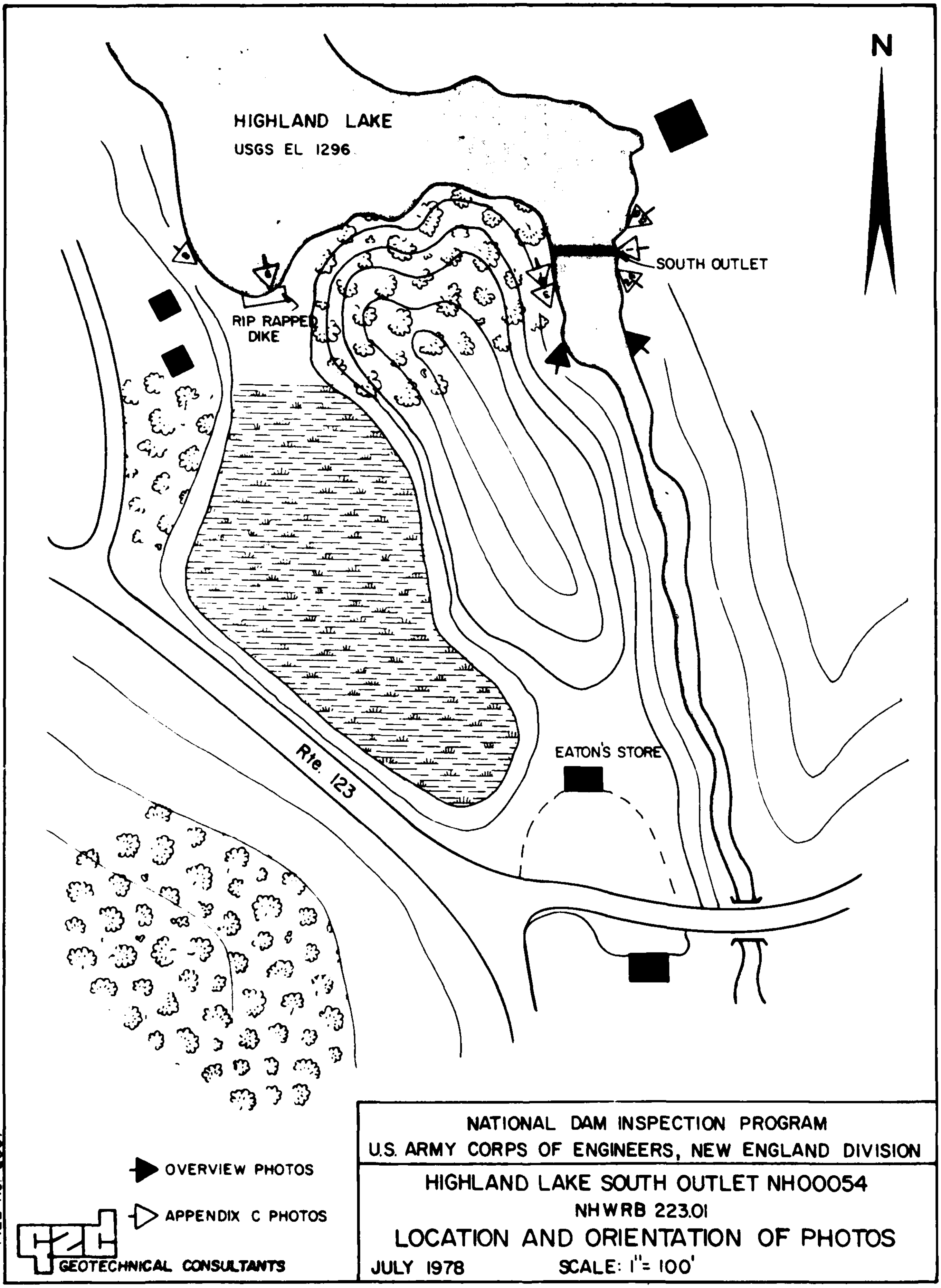
3. View from downstream of sluiceway with stoplogs



4. View from upstream of left abutment, buttress and sluiceway

1. Rock covered earth dike near right abutment from upstream

2. Axis of dam from left abutment



NATIONAL DAM INSPECTION PROGRAM
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION

HIGHLAND LAKE SOUTH OUTLET NH00054
NHWRB 223.01
LOCATION AND ORIENTATION OF PHOTOS

JULY 1978 SCALE: 1" = 100'

FILE No. 2067

APPENDIX C

SELECTED PHOTOGRAPHS

MEMO REGARDING DRAW-DOWN FOR LONG POND SITUATION

James Haddock provided me with the following information on November 3, 1964.

An agreement executed in 1911 between the Town of Stoddard and a predecessor company of Public Service Company of New Hampshire provides that the maximum draw-down at Long Pond shall be 45.6" which is equal to three feet above the mudsill.

R. W. Hunt

The NHWRB maintains the majority of information regarding the Highland Lake South Outlet. Representatives of the Public Service Company of New Hampshire, (PSCNH), indicate that they turned all their records over the NHWRB at the same time the Board assumed ownership of the dam. Included in these records are:

(a) Operating logs from 1969 to the present time.

(b) A 1957 report briefly outlining the power generating capacity of Highland Lake (probably by PSCNH).

(c) Three pages of charts prepared by the PSCNH in 1942-1944 regarding possible discharge rates at the dam.

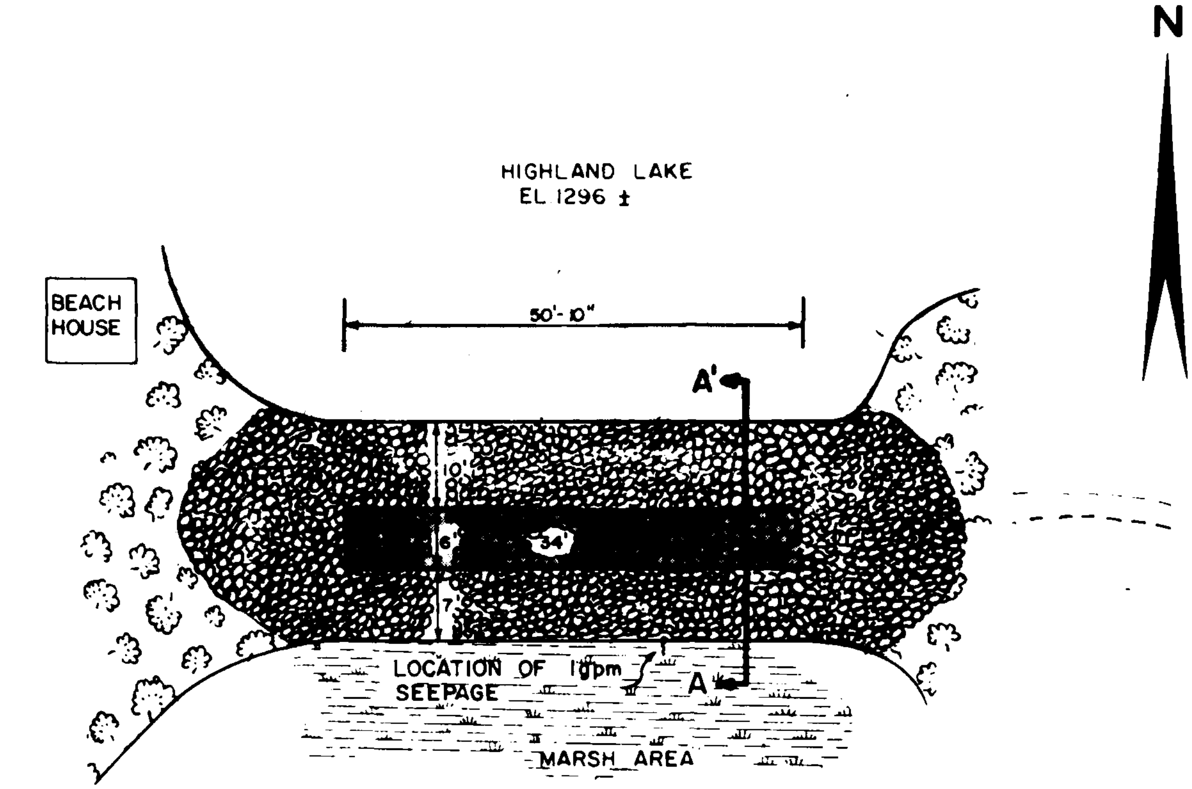
(d) A 1950 report by the PSCNH listing the usable storage capacity in Highland Lake as 2340 acre-feet.

(e) A 1939 report by the New Hampshire Water Control Commission entitled "Data on Dams in New Hampshire".

(f) A 1939 report by the same agency entitled "Data on Reservoirs and Ponds in New Hampshire".

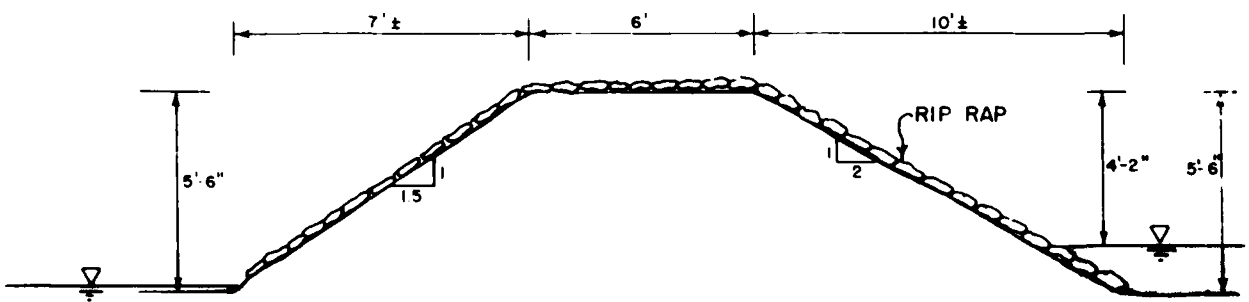
(g) A 1936 report by the NHWRB entitled "Inventory of Dams and Water Power Developments".

Additionally, the tax office in the Town of Stoddard has on hand a series of maps prepared by the Federal Insurance Administration of HUD entitled "Flood Hazard Boundary Map H-01-20 and current as of 17 May 1977.



PLAN VIEW

SCALE 1"=10'



SECTION A-A'

SCALE: 1"= 5'

NOTE:
WATER LEVELS MEASURED
14 JUNE 78.

FILE No. 2067

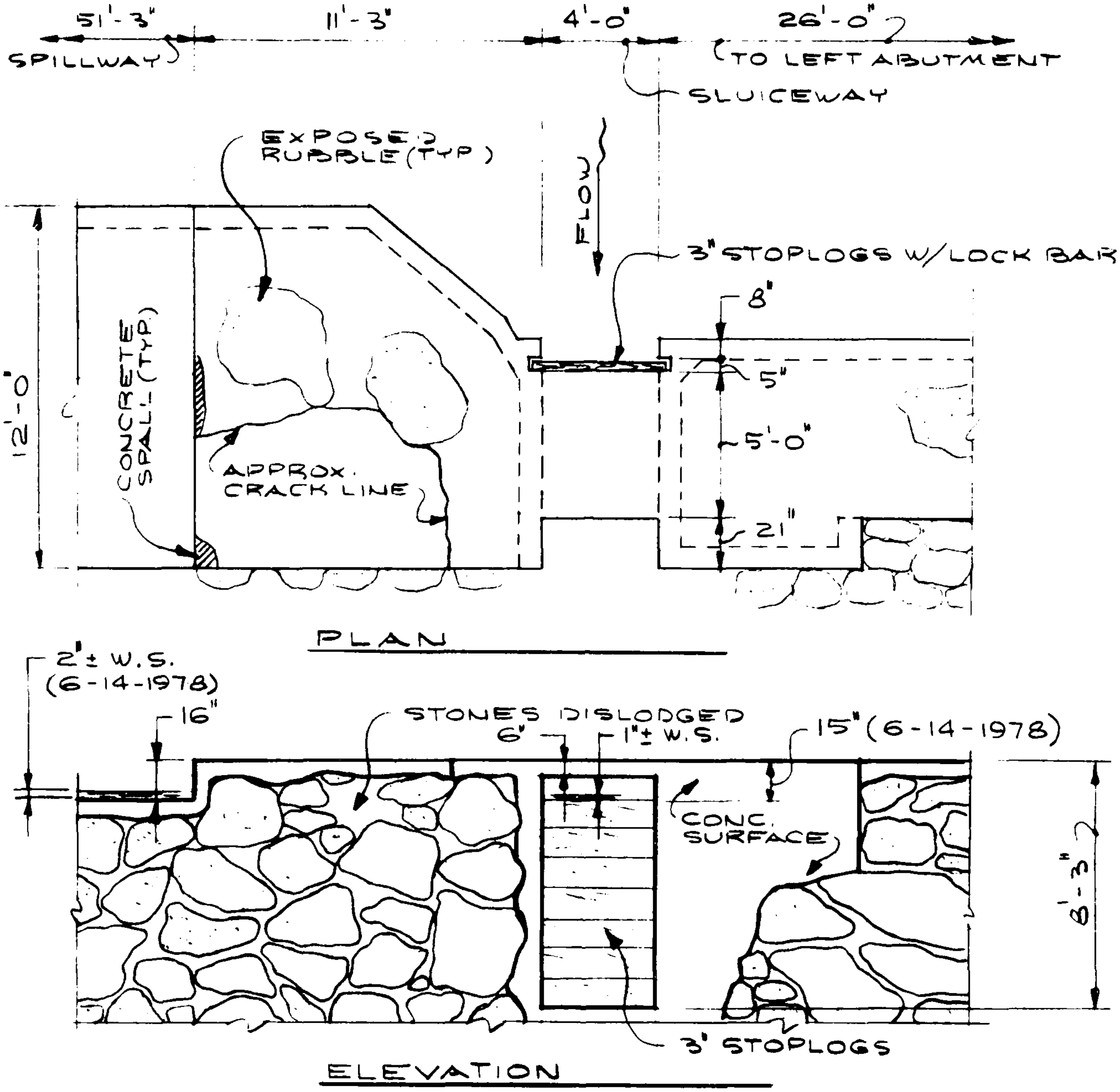
GEOTECHNICAL CONSULTANTS

NATIONAL DAM INSPECTION PROGRAM
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION

HIGHLAND LAKE SOUTH OUTLET NH00054
NHWRB 245.07

SOUTH DIKE, WEST OF SOUTH OUTLET

JULY 1978 SCALE: AS NOTED FIG. 4



SLUICEWAY DETAIL

SCALE: 3/16"=1'-0"

FILE No. 2067

GEOTECHNICAL CONSULTANTS

NATIONAL DAM INSPECTION PROGRAM

U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION

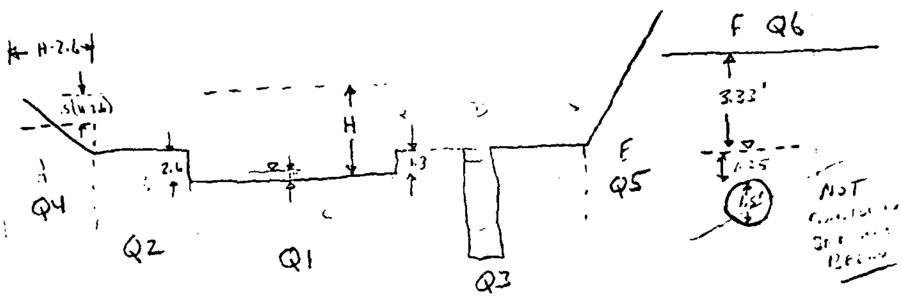
HIGHLAND LAKE SOUTH OUTLET NH00054

NHWRB 223.01

DETAIL OF SLUICEWAY AREA

JULY 1978	SCALE: 3/16"=1'-0"	FIG. 3

FOR THE STAGE DISCHARGE RATING CURVE WE HAVE THE COMBINATION OF FLOW OVER THE SOUTH OUTLET SPILLWAY, THE SOUTH OUTLET STOPLOG SLUICE IF REMOVED AND THE NORTH OUTLET CULVERT.



ASSUME STOPLOGS AT SOUTH OUTLET ARE IN PLACE. ASSUME LAKE WAS FLAT ON [illegible] FIELD SURVEYS WERE CONDUCTED AT 2 ENDS. "H" WILL BE MEASURED AS [illegible] ABOVE PRIMARY SPILLWAY AT [illegible].

FLOW EQUATIONS BY [illegible] SECTION

C: $Q_C = C_C L_C H^{3/2} = C_C (51.25) H^{3/2}$ $C_C = 3.0$

B: $Q_B = C_B L_B (H-2.6)^{3/2} = C_B (14.3)(H-2.6)^{3/2}$ $C_B = 3.0$

A: $Q_A = C_A L_A [.5(H-2.6)]^{3/2} = C_A [H-2.6][.5(H-2.6)]^{3/2}$ $C_A = 2.8$

D: $Q_D = C_D L_D [H-1.3]^{3/2} = C_D [41.25][H-1.3]^{3/2}$ $C_D = 3.0$

E: $Q_E = C_E L_E [.5(H-1.3)]^{3/2} = C_E [H-1.3][.5(H-1.3)]^{3/2}$ $C_E = 2.8$

DAMS 148 | HIGHLAND LAKE #11 #4 | 6-28-78 | DWW | 3/24

F: ASSUME FLAT ROAD 100' LONG

ASSUME CULVERT (18") IS BLOCKED SINCE IT HAS BEEN BLOCKED FOR EACH FIELD TRIP.

ASSUME ROAD IS BREACHED ONCE IT IS OVERTOPPED* ASSUME BREACH IS 40'X4'.

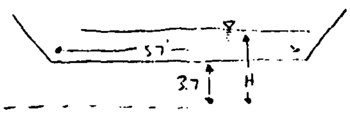
$$H \leq 4.0 \qquad Q_F = C_F(100)(H-3.5)^{3/2}$$

$$H > 4.0 \qquad Q_F = C_F(60)(H-3.5)^{3/2} + C_F(40)(H+.5)^{3/2}$$

* OVERTOPPED BY 0.5'

GOLDSMITH [illegible] BELIEVE [illegible] DIKE [illegible] FAIL SOON AFTER [illegible]. THE TOP OF THE DIKE IS NOMINALLY 3.7 FEET ABOVE THE [illegible] WAY. I'M ASSUMING THAT IT WILL FAIL [illegible] $H > 4.0$ FEET.

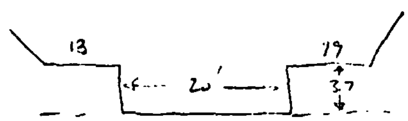
WHEN IT FAILS I'M ASSUMING A SIMPLE SHAPE



ORIGINAL DIKE

DAM SPILLWAY C.L.

FAILED DIKE



DAM SPILLWAY C.L.

IN THE TECHNICAL PROGRAM I USE THE ORIGINAL CONDITION AT $H = 4.0$, BUT USE THE FAILED CONDITION FOR $H = 4.5$. THUS THERE [illegible] JUMP IN THE STAGE DISCHARGE CURVE

$$H \leq 4.0 \quad Q_G = C_G (57)(H-3.7)^{3/2}$$

$$H > 4.0 \quad Q_G = C_G (37)(H-3.7)^{3/2} + C_G (20)(H)^{3/2}$$

$$\text{SIDES:} \quad Q_H = 2.8 \left[2(H-3.7)\right]\left[.5(H-3.7)\right]^{3/2}$$

STORAGE / STAGE RELATIONSHIP

SURFACE AREA OF LAKE AS SHOWN ON NJDWR DATA

711 ACRES

I'LL ASSUME NO SPREADING AS THE WATER SURFACE R[illegible] [illegible] EVERY FOOT THE WATER [illegible]

DRAINAGE AREA = 29.7 SQMI

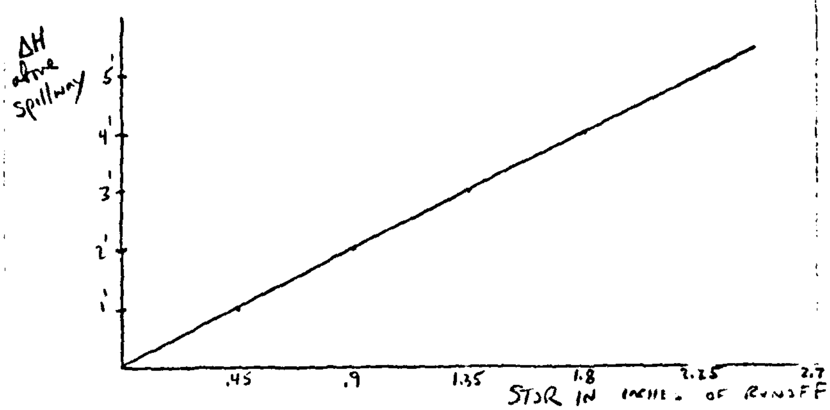
1 inch of runoff would cause

$$\frac{29.7(640)}{711} = 26.73''$$ rise in water surface.

1 foot of rise = .449" of runoff use .45"

2 feet of rise .898" of runoff use .9"

5 feet of rise 2.245" of runoff use 2.25"



DAMS 142 HIGHLAND LAKE $\frac{1}{4}$ 6-19-78 DWard 6 of 24

EFFECT OF SURCHARGE ON MAX. PROBABLE DISCHARGES

For 20,000 cfs, $H \approx 10.2$ FT

$10.2'$ of HEAD EQUATES TO $10.2 \times (.45) = 4.59''$ of RUNOFF

STOR, = 4.6

$$Q_{P2} = Q_{P1} \times \left(1 - \frac{STOR_1}{9.5}\right)$$

$$Q_{P2} = 20,000 \times \left(1 - \frac{4.6}{9.5}\right)$$

$$Q_{P2} = 10337$$

For 10337 cfs, $H \approx 7.1'$

$STOR_2 = 7.1 \times .45'' = 3.2''$

AVG STOR $\frac{4.6 + 3.2}{2} = 3.9''$

$$Q_{P3} = 20000 \times \left(1 - \frac{3.9}{9.5}\right) = 11789 \approx 11800 \text{ cfs}$$

Thus THE STF RESULTS IN A DISCHARGE OF ≈ 11800 cfs TOTAL AND A HEAD ABOVE THE SOUTH SPILLWAY OF 7.6'. THIS REPRESENTS A TOTAL FLOW OF ≈ 3950 CFS OUT THE NORTH OUTLET, 5850 CFS OVER THE SOUTH DAM, AND 2000 CFS THROUGH THE BREACHED SOUTH DIKE.

COMMENTS ON RESULTS:

THE SPILLWAY OF 51.25 HAS A MAX. OF 1.3' OF FREEBOARD BEFORE THE EAST ABUTMENT IS OVERTOPPED. THIS REPRESENTS A CAPACITY OF 228 CFS. THE VICINITY OF THE DAM INCLUDING OVERFLOW OVER THE ABUTMENTS — HAS A MAX. CAPACITY OF 1700 cfs AT A HEAD OF 3.7' ABOVE THE SPILLWAY. ABOVE 3.7' THE SOUTH DIKE BEGINS TO BE OVERTOPPED. ABOVE 3.5' THE NORTH OUTLET ROAD EMBANKMENT IS OVERTOPPED. THE ANALYSIS ASSUMES THAT BOTH OF THESE AREAS FAIL WITH A 20' WIDE AND 3.7' DEEP GAP AT THE SOUTH DIKE, AND A 40' WIDE, 4' DEEP GAP AT THE NORTH OUTLET. WHEN THE DIKES FAIL IT IS IMPOSSIBLE TO PREDICT EXACTLY HOW WIDE A GAP WILL RESULT. IN ADDITION THE BREAKS MAY BECOME SURCHARGED FROM DOWNSTREAM BACKWATERS AND THUS THE USE OF THE WEIR EQUATION IS GENEROUS FROM AN OUTFLOW CONSIDERATION, SINCE ANY TAILWATER ON A CHANNEL FLOW ANALYSIS WOULD REDUCE THE OUTFLOW.

GIVEN THESE COMBINATIONS OF DISCHARGE CONDITIONS AND SURCHARGE STORAGE A PEAK INFLOW OF 20,000 CFS COULD RESULT IN A DISCHARGE OF 11,800 CFS AND A LAKE ELEVATION 7.6' ABOVE THE DAM SPILLWAY CREST.

TOTAL DISCHARGE FROM HIGHLAND LAKE AS FUNC OF HEAD

HEAD	DISCHARGE			
	TOTAL	DAM	SOUTH DIKE	NORTH OUTLET
0.5	54	54	0	0
1.0	154	154	0	0
1.5	294	294	0	0
2.0	508	508	0	0
2.5	772	772	0	0
3.0	1088	1088	0	0
3.5	1455	1455	0	0
4.0	1990	1864	26	99
4.5	4342	2311	610	1420
5.0	5331	2794	783	1753
5.5	6413	3310	981	2121
6.0	7578	3858	1200	2520
6.5	8823	4437	1439	2947
7.0	10142	5044	1697	3400
7.5	11533	5681	1973	3878
8.0	12992	6346	2267	4379
8.5	14517	7037	2577	4902
9.0	16106	7755	2904	5446
9.5	17758	8500	3247	6011
10.0	19471	9270	3606	6595
10.5	21243	10065	3981	7197
11.0	23075	10885	4371	7818
11.5	24964	11729	4777	8457
12.0	26909	12598	5198	9113
12.5	28910	13490	5634	9786
13.0	30967	14407	6085	10475
13.5	33077	15346	6551	11180
14.0	35242	16309	7032	11900

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Summary file 11

```
LIST
100 REM STAGE DISCHARGE CALC FOR HIGHLAND LAKE DAM JOB 148LIST
110 PAGE
120 C1=3
130 C2=2.8
140 E=1.5
150 PRINT "TOTAL DISCHARGE FROM HIGHLAND LAKE AS FUNC OF HEAD"
160 PRINT USING 170:
170 IMAGE // 2T"HEAD"30T"DISCHARGE"
180 PRINT USING 190:
190 IMAGE 10T"TOTAL     DAM   SOUTH DIKE   NORTH OUTLET"
200 FOR H=0.5 TO 14 STEP 0.5
210 Q1=C1*51.25*H↑E
220 Q2=0
230 Q4=0
240 IF H<=2.6 THEN 270
250 Q2=C1*14.3*(H-2.6)↑E
260 Q4=C2*(H-2.6)*(0.5*(H-2.6))↑E
270 Q3=0
280 Q5=0
290 IF H<=1.3 THEN 320
300 Q3=C1*41.25*(H-1.3)↑E
310 Q5=C2*(H-1.3)*(0.5*(H-1.3))↑E
320 Q6=0
330 IF H<=3.5 THEN 350
340 Q6=C2*100*(H-3.5)↑E
350 Q8=0
360 Q9=0
370 IF H<=3.7 THEN 430
380 Q8=C2*57*(H-3.7)↑E
390 Q9=C2*(2*(H-3.7))*(0.5*(H-3.7))↑E
400 IF H<=4 THEN 430
410 Q8=C2*37*(H-3.7)↑E+C2*20*H↑E
420 Q6=C2*60*(H-3.5)↑E+C2*40*(H+0.5)↑E
430 Q7=Q1+Q2+Q3+Q4+Q5+Q6+Q8+Q9
```

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```
431 F1=Q1+Q2+Q3+Q4+Q5
432 F2=Q8+Q9
440 PRINT USING 450:H,Q7,F1,F2,Q6
450 IMAGE 1T,2D.1D,8D,9D,11D,11D
460 NEXT H
470 END
```

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TOTAL DISCHARGE FROM HIGHLAND LAKE AS FUNC OF HEAD

HEAD				DISCHARGE					
	TOTAL	Q1	Q2	Q3	Q4	Q5	Q6	Q8	Q9
0.5	54	54	0	0	0	0	0	0	0
1.0	154	154	0	0	0	0	0	0	0
1.5	294	282	0	11	0	0	0	0	0
2.0	508	435	0	72	0	0	0	0	0
2.5	772	608	0	163	0	2	0	0	0
3.0	1088	799	11	274	0	4	0	0	0
3.5	1455	1007	37	404	1	7	0	0	0
4.0	1990	1230	71	549	2	12	99	26	0
4.5	4342	1468	112	708	5	18	1420	609	1
5.0	5331	1719	160	881	9	26	1753	780	4
5.5	6413	1983	212	1065	14	36	2121	973	9
6.0	7578	2260	269	1261	21	47	2520	1184	16
6.5	8823	2548	330	1467	30	61	2947	1413	26
7.0	10142	2847	396	1684	40	77	3400	1658	39
7.5	11533	3158	465	1910	53	95	3878	1918	56
8.0	12992	3479	538	2146	67	115	4379	2191	76
8.5	14517	3810	615	2391	84	138	4902	2477	100
9.0	16106	4151	695	2644	103	163	5446	2776	128
9.5	17758	4502	778	2906	124	191	6011	3087	160
10.0	19471	4862	864	3176	147	221	6595	3409	197
10.5	21243	5231	953	3453	174	254	7197	3742	239
11.0	23075	5609	1044	3739	202	290	7818	4086	285
11.5	24964	5996	1139	4031	234	329	8457	4441	336
12.0	26909	6391	1236	4331	268	371	9113	4805	393
12.5	28910	6795	1336	4638	305	416	9786	5179	455
13.0	30967	7207	1439	4952	345	464	10475	5563	522
13.5	33077	7626	1544	5273	388	515	11180	5956	595
14.0	35242	8054	1651	5601	434	569	11900	6358	674

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LIST
100 REM STAGE DISCHARGE CALC FOR HIGHLAND LAKE DAM JOB 148LIST
110 PAGE
120 C1=3
130 C2=2.8
140 E=1.5
150 PRINT "TOTAL DISCHARGE FROM HIGHLAND LAKE AS FUNC OF HEAD"
160 PRINT USING 170:
170 IMAGE // 2T"HEAD"30T"DISCHARGE"
180 PRINT USING 190:
190 IMAGE  8T"TOTAL     Q1     Q2      Q3     Q4     Q5      Q6      Q8     Q9"
200 FOR H=0.5 TO 14 STEP 0.5
210 Q1=C1*51.25*H↑E
220 Q2=0
230 Q4=0
240 IF H<=2.6 THEN 270
250 Q2=C1*14.3*(H-2.6)↑E
260 Q4=C2*(H-2.6)*(0.5*(H-2.6))↑E
270 Q3=0
280 Q5=0
290 IF H<=1.3 THEN 320
300 Q3=C1*41.25*(H-1.3)↑E
310 Q5=C2*(H-1.3)*(0.5*(H-1.3))↑E
320 Q6=0
330 IF H<=3.5 THEN 350
340 Q6=C2*100*(H-3.5)↑E
350 Q8=0
360 Q9=0
370 IF H<=3.7 THEN 430
380 Q8=C2*57*(H-3.7)↑E
390 Q9=C2*(2*(H-3.7))*(0.5*(H-3.7))↑E
400 IF H<=4 THEN 430
410 Q8=C2*37*(H-3.7)↑E+C2*20*H↑E
420 Q6=C2*60*(H-3.5)↑E+C2*40*(H+0.5)↑E
430 Q7=Q1+Q2+Q3+Q4+Q5+Q6+Q8+Q9
```

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```
440 PRINT USING 450:H,Q7,Q1,Q2,Q3,Q4,Q5,Q6,Q8,Q9
450 IMAGE 1T,2D.1D,7D,7D,6D,7D,6D,6D,7D,7D,6D
460 NEXT H
470 END
```

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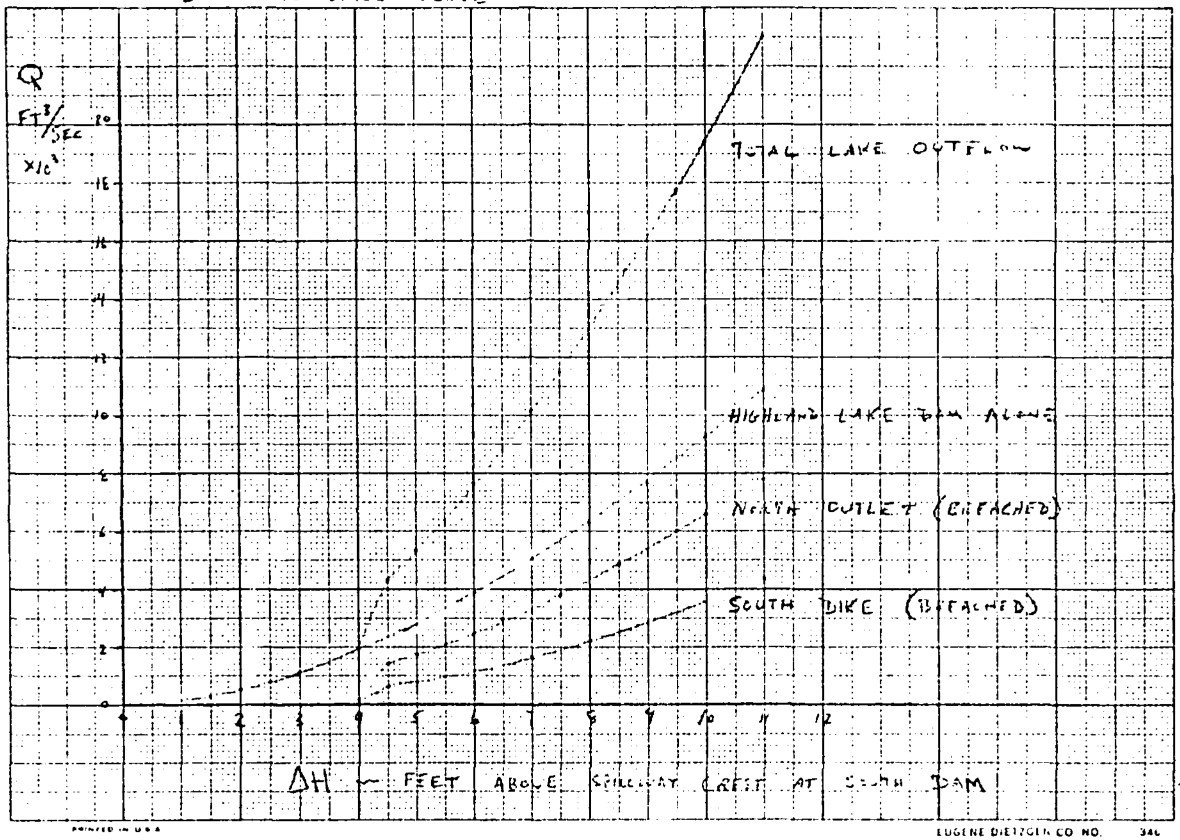
HIGHLAND LAKE DAM #1
NORTH OUTLET # J

6/22/78

DISCHARGE-STAGE CURVE



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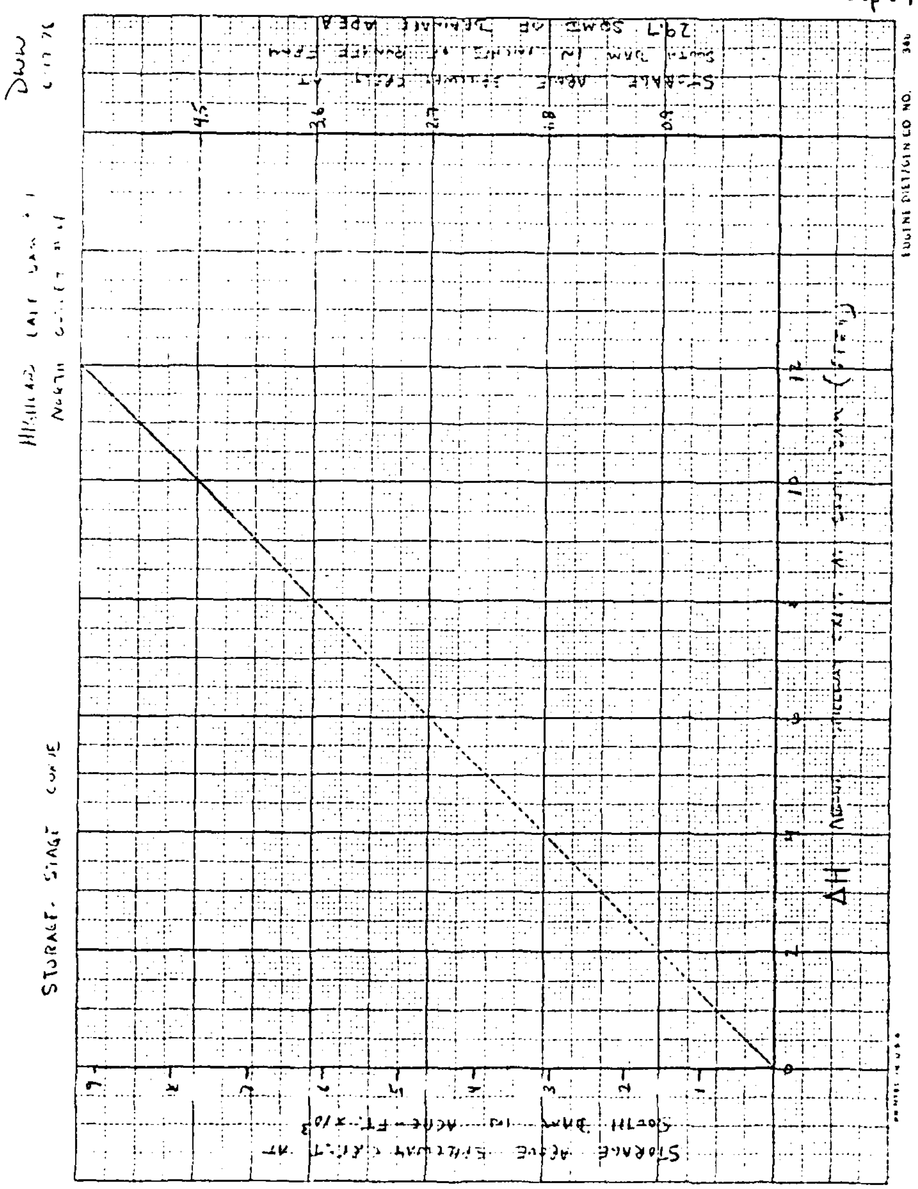


HIGHLAND LAKE DAM DWW 30 JUN 78 17/24

CALC OF ESTIMATED DOWNSTREAM DAM FAILURE FLOOD STAGES – BASED ON COE "RULE OF THUMB" GUIDANCE, APRIL 1978.

STEP 1: RESERVOIR STORAGE AT TIME OF FAILURE

ASSUME: FAILURE WHEN STAGE IS EQUAL TO THE EAST ABUTMENT, OR 1.33' ABOVE THE SPILLWAY CREST.

S = NORMAL STORAGE + SURCHARGE STORAGE

S = 3500 AF + 1.33(711) AF

S = 4450 AF

STEP 2: PEAK FAILURE OUTFLOW (Q_{P1})

$$Q_{P1} = \tfrac{8}{27} W_b \sqrt{g}\, Y_o^{3/2}$$

$$= \tfrac{8}{27}(40)\sqrt{32.2}\,(9)^{3/2}$$

$$= 1816 \text{ cfs}$$

W_b = 40% of width
= .4(100)
= 40

Y_o = 9'

NOTE: THIS FLOW IS CONSIDERABLY LESS THAN THE SDF DISCHARGE

STEP 3: STAGE DISCHARGE RATINGS FOR DOWNSTREAM REACHES

ASSUMED CROSS SECTIONS FOR D.S. REACHES SHOWN ON USGS TOPO MAP ARE PLOTTED ON THE ATTACHED SHEET.

COMPUTER OUTPUT TABLE OF STAGE-DISCHARGE RELATIONSHIPS ARE ATTACHED.

STEP 4:

REACH 1: $Q_{P1} = 1816$ cfs

$H = 2.6'$

AREA ≈ 200 SF

$V_1 = L \times A = 500' \times 200\,SF / 43560 = 2.3\ AF \leq S$

$Q_{P2T} = Q_{P1}\left(1 - \frac{V_1}{S}\right) = 1816\left(1 - \frac{2.3}{4450}\right) = 1815$

NO ATTENUATION

REACH 2: $Q_{P1} = 1815$ cfs

$H = 4.2'$

AREA = 138 SF

$V_1 = L \times A = 1000 \times 138/43560 = 3.17\ AF \leq S$

$Q_{P2T} = 1815\left(1 - \frac{3.17}{4450}\right) \approx 1813$

NO ATTENUATION

REACH 3: $Q_{P1} = 1813$ cfs

$H = 1.9'$

AREA = 350 SF

$V_1 = L \times A = 2000' \times 350\,SF / 43560 = 16.07\ AF \leq S$

$Q_{P2T} = 1813\left(1 - \frac{16.07}{4450}\right) = 1806$

NO SIGNIFICANT ATTENUATION

REACH 4: $Q_{P1} = 1806$ cfs

$H_1 = 2.05'$

AREA = 390 SF

$V_1 = L \times A = 3000' \times 390\,SF / 43560 = 26.86\ AF \leq S$

$Q_{P2T} = 1806\left(1 - \frac{26.86}{4450}\right) = 1795$ cfs

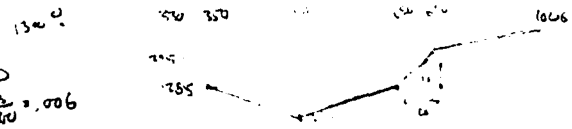
NO SIGNIFICANT ATTENUATION

HIGHLAND LAKE DAM

RLL
29 JUNE 78

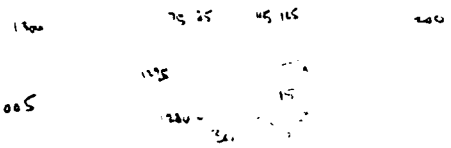
19/24

REACH 1 — POND AREA BELOW DAM



L=500
S: $\frac{3}{500}$ = .006
n: .015

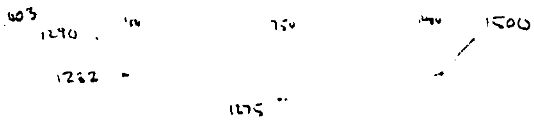
REACH 2 — CHANNEL THROUGH VILLAGE



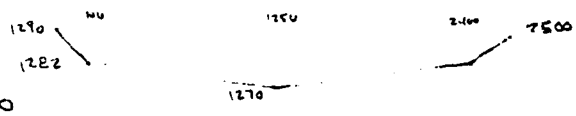
L=1000
S: $\frac{5}{1000}$ = .005
n = .018

REACH 3 — MARSH AREA ABOVE ISLAND POND

L= 2000
S = $\frac{5}{2000}$ = .003
n: .015



REACH 4 — ISLAND POND



L=3000
S: $\frac{5}{3000}$ = .002
n: .015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WASHINGTON
Washington
Farnsworth Hill
Kingsbury Hill
Stoddard Rocks
Copeland Hill
Jackson Hill
Hubbard Hill
Nancy Mtn
Proctor Hill
Holmes Hill
Pitcher Mtn
Hodgeman Hill
Robinson Hill
Parker Hill
Reed Hill
Bacon Ledge
Round Mtn
HIGHLAND LAKE
DAM
REACH 1
REACH 2
REACH 3
REACH 4
Mt Stoddard
Morrison Hill
Dakin Hill
Willard Mtn
SULLIVAN CO
CHESHIRE CO
HILLSBOROUGH CO

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DEPTH	ELEV	AREA	WPER	HYD-R	AR2/3	Q
0.00	1280.0	0.0	0.0	0.0	0.0	0.0
0.25	1280.3	1.9	15.0	0.1	0.5	3.6
0.50	1280.5	7.5	30.0	0.2	3.0	22.9
0.75	1280.8	16.9	45.0	0.4	8.8	67.5
1.00	1281.0	30.0	60.0	0.5	18.9	145.3
1.25	1281.3	46.9	75.0	0.6	34.2	263.5
1.50	1281.5	67.5	90.0	0.7	55.7	428.5
1.75	1281.8	91.9	105.1	0.9	84.0	646.4
2.00	1282.0	120.0	120.1	1.0	120.0	923.0
2.25	1282.3	151.9	135.1	1.1	164.2	1263.6
2.50	1282.5	187.5	150.1	1.2	217.5	1673.6
2.75	1282.8	226.9	165.1	1.4	280.5	2158.0
3.00	1283.0	270.0	180.1	1.5	353.7	2721.6
3.25	1283.3	316.9	195.1	1.6	437.9	3369.3
3.50	1283.5	367.5	210.1	1.7	533.6	4105.6
3.75	1283.8	421.9	225.1	1.9	641.4	4935.0
4.00	1284.0	480.0	240.1	2.0	761.8	5861.9
4.25	1284.3	541.9	255.1	2.1	895.5	6890.6
4.50	1284.5	607.5	270.1	2.2	1043.0	8025.3
4.75	1284.8	676.9	285.2	2.4	1204.8	9270.1
5.00	1285.0	750.0	300.2	2.5	1381.4	10629.1
5.25	1285.3	825.2	301.5	2.7	1615.0	12426.1
5.50	1285.5	900.6	302.9	3.0	1863.1	14335.1
5.75	1285.8	976.4	304.2	3.2	2125.4	16353.2
6.00	1286.0	1052.5	305.6	3.4	2401.5	18477.8
6.25	1286.3	1128.9	306.9	3.7	2691.2	20706.7
6.50	1286.5	1205.6	308.3	3.9	2994.1	23037.7
6.75	1286.8	1282.7	309.6	4.1	3310.1	25469.1
7.00	1287.0	1360.0	311.0	4.4	3638.9	27999.0
7.25	1287.3	1437.7	312.3	4.6	3980.3	30626.0

HIGHLAND LAKE REACH 1

DEPTH	ELEV	AREA	WPER	HYD-R	AR2/3	Q
0.00	1280.0	0.0	0.0	0.0	0.0	0.0
0.25	1280.3	7.5	30.6	0.2	3.0	17.3
0.50	1280.5	15.2	31.2	0.5	9.4	54.9
0.75	1280.8	22.9	31.8	0.7	18.4	107.5
1.00	1281.0	30.7	32.4	0.9	29.6	173.0
1.25	1281.3	38.5	33.0	1.2	42.7	250.2
1.50	1281.5	46.5	33.6	1.4	57.7	338.0
1.75	1281.8	54.5	34.2	1.6	74.5	435.8
2.00	1282.0	62.7	34.8	1.8	92.8	543.0
2.25	1282.3	70.9	35.4	2.0	112.6	659.0
2.50	1282.5	79.2	36.0	2.2	133.9	783.7
2.75	1282.8	87.5	36.6	2.4	156.6	916.5
3.00	1283.0	96.0	37.2	2.6	180.6	1057.3
3.25	1283.3	104.5	37.8	2.8	206.0	1205.8
3.50	1283.5	113.2	38.4	2.9	232.6	1361.8
3.75	1283.8	121.9	39.0	3.1	260.5	1525.0
4.00	1284.0	130.7	39.6	3.3	289.7	1695.4
4.25	1284.3	139.5	40.2	3.5	320.0	1872.8
4.50	1284.5	148.5	40.8	3.6	351.4	2057.0
4.75	1284.8	157.5	41.4	3.8	384.1	2248.0
5.00	1285.0	166.7	42.0	4.0	417.8	2445.6
5.25	1285.3	175.9	42.6	4.1	452.7	2649.8
5.50	1285.5	185.2	43.2	4.3	488.7	2860.4
5.75	1285.8	194.5	43.8	4.4	525.8	3077.4
6.00	1286.0	204.0	44.4	4.6	563.9	3300.7
6.25	1286.3	213.5	45.0	4.7	603.1	3530.2
6.50	1286.5	223.2	45.6	4.9	643.4	3766.0
6.75	1286.8	232.9	46.2	5.0	684.7	4007.9
7.00	1287.0	242.7	46.8	5.2	727.1	4255.9
7.25	1287.3	252.5	47.4	5.3	770.5	4510.0

HIGHLAND LAKE REACH 2

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23-24

DEPTH	ELEV	AREA	WPER	HYD-R	AR2/3	Q
0.00	1275.0	0.0	0.0	0.0	0.0	0.0
0.25	1275.3	5.8	46.4	0.1	1.4	7.9
0.50	1275.5	23.2	92.9	0.2	9.2	50.1
0.75	1275.8	52.2	139.3	0.4	27.2	147.7
1.00	1276.0	92.9	185.7	0.5	58.5	318.2
1.25	1276.3	145.1	232.2	0.6	106.0	576.9
1.50	1276.5	208.9	278.6	0.7	172.4	938.2
1.75	1276.8	284.4	325.0	0.9	260.1	1415.3
2.00	1277.0	371.4	371.5	1.0	371.4	2020.8
2.25	1277.3	470.1	417.9	1.1	508.5	2766.5
2.50	1277.5	580.4	464.3	1.2	673.5	3664.1
2.75	1277.8	702.2	510.7	1.4	868.4	4724.6
3.00	1278.0	835.7	557.2	1.5	1095.2	5958.7
3.25	1278.3	980.8	603.6	1.6	1355.8	7376.7
3.50	1278.5	1137.5	650.0	1.7	1652.1	8988.7
3.75	1278.8	1305.8	696.5	1.9	1985.9	10804.6
4.00	1279.0	1485.7	742.9	2.0	2358.9	12834.0
4.25	1279.3	1677.2	789.3	2.1	2772.8	15086.2
4.50	1279.5	1880.4	835.8	2.2	3229.5	17570.5
4.75	1279.8	2095.1	882.2	2.4	3730.4	20295.9
5.00	1280.0	2321.4	928.6	2.5	4277.2	23271.3
5.25	1280.3	2559.4	975.1	2.6	4871.7	26505.3
5.50	1280.5	2808.9	1021.5	2.7	5515.2	30006.4
5.75	1280.8	3070.1	1067.9	2.9	6209.3	33783.2
6.00	1281.0	3342.9	1114.4	3.0	6955.7	37844.0
6.25	1281.3	3627.2	1160.8	3.1	7755.7	42196.8
6.50	1281.5	3923.2	1207.2	3.2	8611.0	46849.7
6.75	1281.8	4230.8	1253.6	3.4	9522.8	51810.8
7.00	1282.0	4550.0	1300.1	3.5	10492.7	57087.8
7.25	1282.3	4875.8	1306.3	3.7	11737.1	63857.9

HIGHLAND LAKE REACH 3

DEPTH	ELEV	AREA	WPER	HYD-R	AR2/3	Q
0.00	1270.0	0.0	0.0	0.0	0.0	0.0
0.25	1270.3	6.0	47.9	0.1	1.5	6.6
0.50	1270.5	24.0	95.8	0.2	9.5	42.2
0.75	1270.8	53.9	143.8	0.4	28.0	124.5
1.00	1271.0	95.8	191.7	0.5	60.4	268.1
1.25	1271.3	149.7	239.6	0.6	109.4	486.2
1.50	1271.5	215.6	287.5	0.7	178.0	790.6
1.75	1271.8	293.5	335.4	0.9	268.5	1192.6
2.00	1272.0	383.3	383.4	1.0	383.3	1702.8
2.25	1272.3	485.2	431.3	1.1	524.8	2331.3
2.50	1272.5	599.0	479.2	1.2	695.1	3087.7
2.75	1272.8	724.7	527.1	1.4	896.2	3981.3
3.00	1273.0	862.5	575.0	1.5	1130.3	5021.2
3.25	1273.3	1012.2	623.0	1.6	1399.3	6216.1
3.50	1273.5	1174.0	670.9	1.7	1705.1	7574.5
3.75	1273.8	1347.7	718.8	1.9	2049.5	9104.7
4.00	1274.0	1533.3	766.7	2.0	2434.5	10814.8
4.25	1274.3	1731.0	814.6	2.1	2861.7	12712.7
4.50	1274.5	1940.6	862.5	2.2	3333.0	14806.1
4.75	1274.8	2162.2	910.5	2.4	3850.0	17102.7
5.00	1275.0	2395.8	958.4	2.5	4414.4	19610.0
5.25	1275.3	2641.4	1006.3	2.6	5027.8	22335.1
5.50	1275.5	2899.0	1054.2	2.7	5692.0	25285.5
5.75	1275.8	3168.5	1102.1	2.9	6408.4	28468.1
6.00	1276.0	3450.0	1150.1	3.0	7178.7	31889.9
6.25	1276.3	3743.5	1198.0	3.1	8004.3	35557.9
6.50	1276.5	4049.0	1245.9	3.2	8887.0	39478.8
6.75	1276.8	4366.4	1293.8	3.4	9828.0	43659.3
7.00	1277.0	4695.8	1341.7	3.5	10829.0	48106.1
7.25	1277.3	5037.2	1389.7	3.6	11891.5	52825.7

HIGHLAND LAKE REACH 4

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APPENDIX E

REVISED INVENTORY FORMS

END

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